An-Najah National University

Faculty of Graduate Studies

BACTERIAL PROFILE AND ANTIBIOTIC SUCEPTIBILITY PATTERNS IN HOSPITALIZED PATIENTS WITH INFECTED DIABETIC FOOT

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Dedication

First, I dedicate this project to God Almighty, my creator, my strong pillar, and my source of inspiration.

I dedicate this to my beloved husband and best friend, Dr. Abdallah.

To my lovely daughters Hala, Hoor, & Sham.

To my whole family, thank you all.

With heartfelt gratitude,

Aseel Khader Hammad

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With sincere appreciation,

Aseel Khader Hammad

Declaration

I am the undersigned, declare that I submitted the thesis entitled:

BACTERIAL PROFILE AND ANTIBIOTIC SUCEPTIBILITY PATTERNS IN HOSPITALIZED PATIENTS WITH INFECTED DIABETIC FOOT

I declare that the work provided in this thesis, unless otherwise referenced, is the researcher's own work, and has not been submitted elsewhere for any other degree or qualification.

Student's Name: Aseel Khader Hammad

Signature: 

Date: 5/8/2025

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Abstract

Background: Diabetes mellitus (DM) represents a major public health concern and has been increasingly associated with serious complications. One of the most complex and costly complications of diabetes is diabetic foot infection (DFI). Early diagnosis, promote treatment based on pathogen identification and antibiotic susceptibility testing, is essential for achieving favorable clinical outcomes. The aim of this study is to assess the bacterial profile and antibiotic susceptibility patterns in patients with infected diabetic foot.

Methodology: A retrospective design to evaluate bacterial profile and antibiotic susceptibility patterns in patients with infected diabetic foot ulcers (DFUs) was used. The study was conducted at Salfeet Governmental Hospital. The files of all type 2 diabetes mellitus patients who meet the inclusion criteria during the previous three years were included. (SPSS) was used for data analysis.

Results: The study included 211 participants, in which the majority (45.0%) aged between 50-59 years, & males comprised 66.8% of the sample. Regarding diabetes mellitus (DM) duration, most participants (87.2%) had been diagnosed for > 10 years. Neuropathy was present in 34.6%, nephropathy in 24.6%, and angiopathy in 8.5% of the study population. Among the study participants, the most common ulcer site was the forefoot (33.1%). Ulcers penetrating to the bone (Grade D) were present in 20.4% of cases, and 7.1% had ulcers with osteomyelitis or abscess (Grade E). A statistically significant association was found between nephropathy and severity of ulcer grade ($p = 0.007$). The most commonly isolated microorganism was Escherichia coli, detected in 26.5% of cases, followed by Staphylococcus aureus (20.9%) and Pseudomonas aeruginosa (10.9%). Among the antibiotics tested for sensitivity, Meropenem/Ertapenem showed the highest sensitivity, with 63.03%, followed by

Amikacin at 47.39%, Gentamycin (40.28%), and Piperacillin+ Tazobactam (39.81%). Amoxicillin + Clavulanic acid showed the lowest sensitivity, at only 3.79%,

Conclusion**:** The microbiological profiles revealed a high prevalence of Gram-negative bacteria, notably Escherichia coli, and Pseudomonas aeruginosa, accompanied by considerable treatment resistance. Meropenem, was the most often prescribed and effective antibiotic. The results affirm the necessity for multidisciplinary management strategies that encompass early detection, prompt surgical and antimicrobial interventions to enhance clinical outcomes and reduce amputations.

Keywords: diabetic foot ulcer; antimicrobial susceptibility; bacterial types; Palestine.

Chapter One

Introduction and Theoretical Background

1.1 Background

Diabetes mellitus (DM) is a significant public health issue that has been associated with an increase in major consequences (Tomic et al., 2022). There are 422 million individuals with diabetes worldwide, according to World Health Organization figures as of June 2024. By 2030, 578 million more people worldwide are predicted to have diabetes (Senneville et al., 2024). Type 2 diabetes (T2DM) is a diverse range of illnesses that primarily affect older adults. It is typified by decreased insulin secretion, varying levels of insulin resistance, and elevated glucose production (Galicia-Garcia et al., 2020). Adults are more likely to develop diabetes mellitus with an early onset, particularly in developed nations. The STEPWISE study calculated that 20.8% of Palestinians aged 40 to 69 had diabetes in 2022. When this prevalence was broken down further by gender, rates of 17.3% for men and 24.3% for women were found. Furthermore, data from the Palestinian Ministry of Health (PMOH) for 2021 showed an incidence rate of 166.9 per 100,000 people (PNIPH. 2022).

Numerous infections, including those of the skin, mucous membranes, soft tissues, urinary system, respiratory tract, and surgical or hospital-associated infections, are linked to diabetes mellitus, the explanation underlying this frequent relationship with infections is an immunocompromised state of diabetic patients because uncontrolled hyperglycemia lowers overall immunity via participation of different mechanistic pathways that lead to the diabetic patients as immunocompromised (Akash et al., 2020).

Diabetic foot infection (DFI) is one of the consequences that can arise from diabetes mellitus, an endocrine condition. Patients with DFI who have Type 1 or Type 2 diabetes have a 34% lifetime risk (Armstrong et al., 2017). Diabetes patients are at risk for developing DFI due to circulatory issues brought on by diabetic peripheral neuropathy and peripheral arterial disease. DFI infections range from straightforward superficial cellulitis to persistent osteomyelitis (Amin and Doupis, 2016). Diabetes has a complicated condition called DFI, which is expensive to treat. Besides being a major cause of morbidity, DFI is the leading cause of non-traumatic major proximal

amputation and is responsible for a high hospital admission and hospital length-of-stay burden in people with diabetes.

Furthermore, the risk of death of diabetic patients with DFI is as much as 2.5 times higher than that of those without DFI (Lipsky et al., 2020).

A patient with a diabetic foot ulcer is 2.5 times more likely to die within 5-years than patient without diabetes. About 20 % of cases which have infections between moderate to severe degree may ended with amputation.

Furthermore, at two years, 74% of them also run the risk of needing renal replacement treatment. Coexisting comorbidities such as cardiovascular or cerebrovascular illnesses are also linked to this increased death rate (Zhang et al., 2017) (Guariguata, 2012).

A major factor contributing to morbidity and death in diabetic ulcerated feet is infection. Diabetes patients are known to have weakened host defenses, which include reduced leukocyte capacity and morphologic changes to macrophages, increased pro-inflammatory cytokines, and impaired functions of diabetic polymorph-nuclear cells (chemotaxis, phagocytosis, and killing). The trio of neuropathy, peripheral artery disease, and concurrent secondary bacterial infection is the basis of DFI pathophysiology, peripheral neuropathy may result in intrinsic muscle atrophy and modifications to the foot's functional anatomy (Akkus and Sert, 2022).

The severity of DFI also determines the type of infection, whether it is polymicrobial or monomicrobial, while moderate infections are often monomicrobial, the severe form of DFI is typically caused by polymicrobial infections. It is possible to cultivate up to three or five organisms in severe cases of DFI. The degree of the disease influences the bacteriological profile of DFI. The most prevalent pathogens include Streptococcus pyogenes, Staphylococcus aureus, Pseudomonas aeruginosa, Escherichia coli, Klebsiella pneumoniae, Acinetobacter spp., Proteus spp., and Enterococcus spp. (Lipsky et al., 2020). Both Gram-positive and Gram-negative bacteria, as well as fungus and anaerobic bacteria, are thought to be possible sources of infection. A favorable outcome depends on early detection of DFU infection and adequate treatment chosen after pathogen identification and antibiotic susceptibility pattern analysis (Atlaw et al., 2022).

1.2 Problem Statement

More diabetic patients are currently admitted to hospitals for foot problems than for any other diabetic complication. Diabetic foot infections—especially those that penetrate the bone—are the main cause of lower-extremity amputation in diabetic patients, which raises the risk of death and increases the financial burden (Baig et al., 2022). Important issue for world public health. It has an impact on people's entire lives and on their quality of life. Due to complications, as DFI which may lead to amputation, an elevated cardiovascular disease, stroke, kidney damage and blindness, the expense of treating diabetes is rising substantially (Al-Joufi et al., 2020).

In clinical practice, clinicians typically face complex and challenging DFU management. The estimated expenses for managing DFUs in both developed and developing nations exceed one billion dollars. Foot ulcers should be treated immediately by a multidisciplinary specialized team for optimal outcomes. Treatment of DFU requires a systematic methodology and a timely decision-making process. This includes controlling the infection, maintaining arterial blood flow, and releasing pressure from the wound (Margolis et al., 2008).

Finding the bacteria that cause diabetic foot infections is crucial for directing efficient treatment, establishing appropriate infection control procedures, and lowering the risk of complications that could result in sepsis or amputation while also shortening hospital stays. In addition to being the primary cause of amputation, diabetic foot infections (DFIs) are associated with substantial morbidity, increased mortality, and a worse quality of life. Choosing the appropriate antibiotics is essential to reducing treatment failure, antimicrobial resistance, side effects, and costs. (Kwon and Armstrong, 2018).

In order to guide effective therapy and establish appropriate infection control policies, as well as to reduce the risk of complications that could result in amputation or sepsis, shorten hospital stays, and improve quality of life, it is crucial to investigate the bacterial profile and antibiotic susceptibility patterns among hospitalized patients with infected diabetic foot. in addition to lessening the financial strain on patients and the Palestinian healthcare system.

1.3 Significance of the study

Clinical Importance: Among people with diabetes, diabetic foot infections (DFIs) are one of the most frequent causes of lower extremity amputations. The research identified the specific bacterial species responsible for DFIs and ascertain their antibiotic resistance profiles, enabling medical professionals to avert the direst consequences, like amputation and sepsis.

Enhancement of Patient Outcomes: This research can offer helpful suggestions for shortening hospital stays, improving rehabilitation results, and improving the quality of life for diabetic foot infection patients. This may directly lower the rate of premature patient mortality and lower the likelihood of long-term impairment.

Resource Optimization: Addressing the issue of antibiotic resistance may help determine which antibiotics are appropriate for a certain disease and how to best treat it. Additionally, since the abuse of antibiotics would be discouraged, there will be less waste of health care dollars and, if needed, shorter hospital stays.

Relevance to Public Health: DFIs are among the complications of diabetes in Palestine, and the disease is one of the most prevalent non-communicable diseases worldwide. In order to properly manage the condition, this work can be crucial in providing local data for the creation of public health campaigns aimed at lowering the incidence of diabetic foot infections.

Economic Impact: By identifying the bacterial exposure and promoting appropriate antibiotic treatment, the financial burden on Palestinian patients and the healthcare system as a whole can be reduced. By reducing amputations, long-term patient care, and hospital readmissions, among other things, this research on infection control and complications reduction may significantly lower the expenses of treating diabetes.

1.4 Aim and objectives of the study

The aim of this study is to assess the bacterial profile and antibiotic susceptibility patterns in patients with infected diabetic foot.

Specific objectives:

- To find the severity and site of DFI among patients.
- To assess the bacterial profile and find the most common bacterial causes of DFI.
- To assess the antibiotic susceptibility of the bacteria that cause DFI by reviewing culture and sensitivity reports.
- To find the most commonly used antibiotics and their duration of use.
- To evaluate the outcomes of treatment.
- To find any possible associations between some sociodemographic and clinical variables with ulcer severity, resistance and outcomes.

1.5 Research Questions

- What is the bacterial profile of pathogens responsible for diabetic foot infections
- among hospitalized diabetic patients?
- What are the antibiotic susceptibility patterns of the bacteria identified in diabetic foot infections?
- Is there is a relationship between some factors and clinical improvement among DFI patients?

1.6 Literature Review

1.6.1 Introduction

This chapter serves as a comprehensive exploration into various critical facets surrounding the bacterial profile, antibiotic susceptibility patterns and infected diabetic foot. Through an in-depth examination of pertinent literature, drawn from reputable sources such as scholarly articles, Cochrane reviews, PubMed, and other academic databases, this chapter aims to elucidate the intricate interplay between bacterial profile, antibiotic susceptibility patterns and infected diabetic foot.

1.6.2 Pathophysiology of diabetic foot ulcer

A number of biochemical disorders, such as hyperglycemia, which prevents endothelial nitric oxide synthase from being produced and activated, and the Maillard reaction, which is connected to aging and diabetic complications, can hasten neuropathy and vascular foot changes. DFUs can result from ischemia, neuropathy, or both. Understanding the involvement of several contributing elements, such as peripheral neuropathy, vascular disease (arterial circulation), inflammatory cytokines, and susceptibility to infection, is necessary to understand the pathophysiology of DFUs (Alavi et al., 2014).

The pathogenesis of diabetic ulcers involves immune system abnormalities and neuropathy. These factors can occur and advance concurrently, with diabetic neuroarthropathy arising from the interplay of metabolic dysfunction, diabetes immunopathy, diabetic neuropathy, and diabetic angiopathy (Kim, 2023).

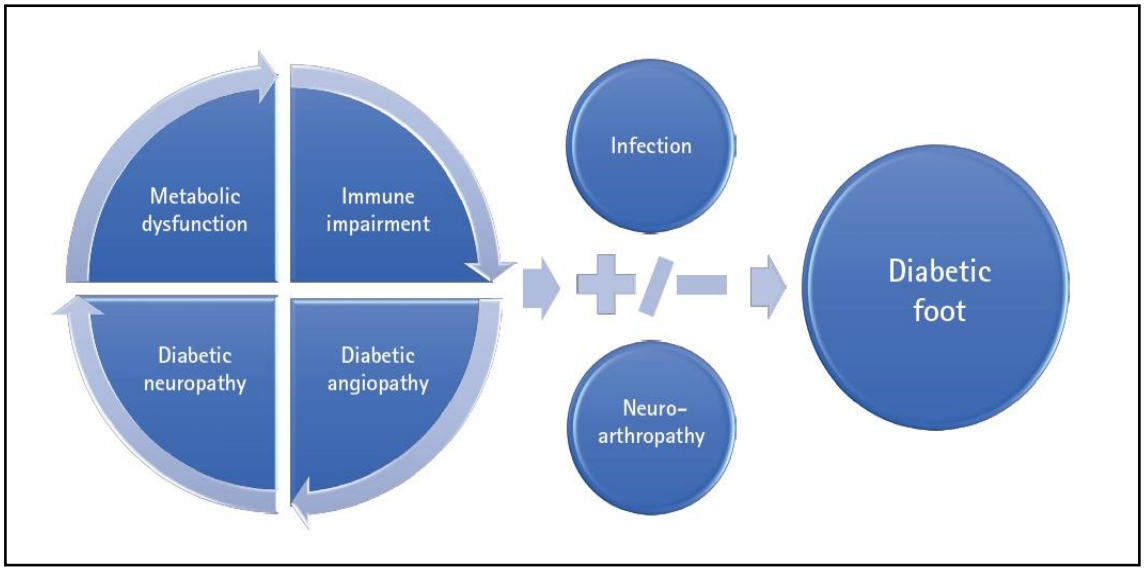
1.6.3 Diabetic foot infections

In diabetics, the interaction of immunopathy, diabetic neuropathy, diabetic angiopathy, and metabolic variables facilitates the onset and advancement of infections, ischemic ulcers, and gangrene, which may result in amputation (Schaper et al., 2017).

DFIs can be caused by a variety of bacteria, the most common of which is Staphylococcus aureus. In 16.78% to 30% of DFI cases, methicillin-resistant S. aureus (MRSA) is present. MRSA infections are linked to higher rates of hospitalization and a higher chance of limb amputation, even if they don't seem to have an impact on death. It has been demonstrated that amputation increases life expectancy by two years in half of the diabetes study subjects as a prophylactic measure against the spread of infection. However, five years after the first appearance of ulcers, the survival percentage for patients with diabetes and ulcerative infections is still just 56% (Stacey et al., 2019), (Saltoglu et al., 2018). (figure1)

Figure 1

The pathophysiology of diabetic foot: a narrative review



1.6.4 DF Ulcer grades classification

Diabetic foot ulcers (DFUs) are categorized according to a number of factors such as the depth severity and underlying cause. The University of Texas classification and the Wagner classification are two popular classification schemes. These systems support medical professionals in determining the extent of ulcers directing therapy and forecasting healing results.

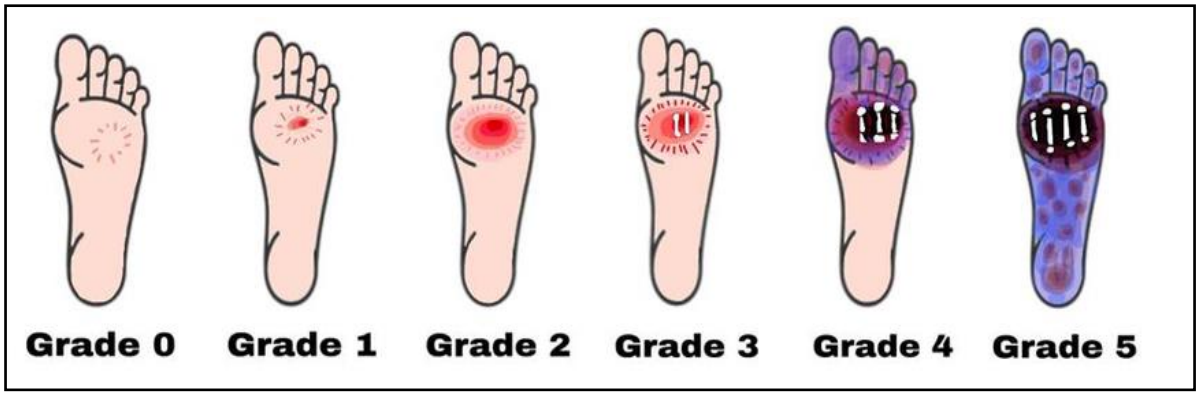
1.6.5 Wagner Categorization Scheme

One of the most widely used classification schemes for diabetic foot ulcers is the Wagner classification scheme. Six grades are used to classify ulcers according to their depth and whether or not they are infected or ischemic (Mehraj and Shah, 2018) .

- Grade 0: No ulcer; the foot is at risk (e.g., a patient with neuropathy or deformity).
- Grade 1: Superficial ulcer; involving only the skin (epidermis and dermis).
- Grade 2: Ulcer penetrating to tendons or capsule; does not involve bone.
- Grade 3: Deep ulcer; involving bone or joint (osteomyelitis).
- Grade 4: Localized gangrene; affecting the forefoot or heel.
- Grade 5: Extensive gangrene; requiring possible amputation.

Figure 2

Wagner classification scheme



Source: (Ansari et al., 2022) study.

1.6.6 University of Texas Classification System

In addition to taking into account the ulcers depth and the existence of infection or ischemia the University of Texas (UT) classification system for diabetic foot ulcers offers additional information about the wounds characteristics (Santema et al., 2016):

- Grade A: No ulcer; at risk.
- Grade B: Superficial ulcer; skin (epidermis) involved.
- Grade C: Ulcer extending to tendon or capsule.
- Grade D: Ulcer penetrating to bone.
- Grade E: Ulcer with osteomyelitis or abscess.

Each grade is further classified by stage based on the presence of infection and ischemia:

- Stage 1: No infection, no ischemia.
- Stage 2: Infection present, no ischemia.
- Stage 3: Ischemia present, with or without infection.
- Stage 4: Both infection and ischemia present.

1.6.7 IDSA (Infectious Diseases Society of America) Classification

A classification system for diabetic foot infections is also offered by the Infectious Diseases

Society of America (IDSA) and it is based on the infections severity rather than just the depth of the ulcer (Lipsky et al., 2020).

- Mild: Localized infection; typically treated with oral antibiotics.
- Moderate: More extensive infection; requires broader antibiotic coverage and possible hospitalization.
- Severe: Infection associated with systemic inflammatory response syndrome (SIRS); requires urgent intervention, potentially including surgery.

1.6.8 Previous Studies

The bacterial patterns and antibiotic susceptibility in diabetic foot infections (DFI) were investigated in patients in Lampung Province, Indonesia, in a research by (Darwis et al., 2021). 131 DFI patients who were admitted to Dr. Hi Abdul Moeloek Regional General Hospital between 2017 and 2019 were included in this retrospective review, which made use of medical records with information on antibiotic susceptibility, wound culture, clinical, and laboratory data.

Present in Enterobacter spp., the findings in the study, against virtual screening and generation of mutant homology models. was the predominant pathogen and was isolated in 85.5% of the cases, usually with other Gram-negative organisms. Gram n positive bacteria were obtained from 14.5 percent of patients, with the majority of isolates being Staphylococci. The high susceptibility of Gram-positive and Gram-negative organisms to meropenem, amikacin, and Sulbactam/Cefoperazone in this study indicated the effectiveness of these antibiotics for the treatment of DFI in this group.

A study conducted in Turkey in 2024 looked at the microbiological spectrum and patterns of antimicrobial resistance in diabetic foot infections (DFIs) in order to assist doctors in selecting the appropriate empirical antibiotics (Coşkun et al., 2024). This retrospective analysis investigated 432 isolates from 262 DFI patients between January 2021 and December 2022. The results showed that 1.2% of the isolates were Candida

species, 41.2% were Gram-positive bacteria, and 57.6% were Gram-negative bacteria. Staphylococcus species were the most common Gram-positive bacteria. Gram-negative bacteria included Pseudomonas aeruginosa and Escherichia coli. Forty-five percent of patients had polymicrobial illnesses. The percentage of extended-spectrum beta-lactamase (ESBL) resistance in E. coli was 66.7%, whereas the rate of methicillin-resistant Staphylococcus species was 51.3%. Since these data demonstrate the increasing difficulties in treating DFIs due to escalating antibiotic resistance, an understanding of local microbial profiles is essential for effective empirical treatment.

A retrospective multicenter surveillance study was conducted in 2020 to assess risk factors for clinical consequences associated with diabetic foot infections (DFIs) and microbiological profile patterns of antibiotic sensitivity (Al-Joufi et al., 2020). Data from 792 diabetic foot patients (DFPs) were analyzed, and 1803 causal organisms were identified. Polymicrobial infections were present in 48.5% of patients. The study found that Gram-positive pathogens (46.7 percent) were more prevalent than anaerobic organisms (7.9 percent) and Gram-negative pathogens (38.6 percent). The predominant pathogens were Staphylococcus aureus (22.2 percent), Enterococcus species, and methicillin-resistant S. aureus (7.7 percent). (12.8 percent), Pseudomonas aeruginosa (9.4 percent), and Escherichia coli (7.9 percent). Vancomycin and clindamycin were unsuccessful against Gram-positive bacteria, while Imipenem and Meropenem showed great efficiency against Gram-negative isolates. Biofilm formation was also detected in 49.8% of the strains. These findings highlighted the need for tailored therapeutic approaches in the management of DFIs, given the diverse microbiological etiology and patterns of antibiotic resistance.

To assess the prevalence of causative organisms in diabetic foot ulcers their susceptibility to antibiotics and related risk factors a cross-sectional study was carried out by (Amjad et al., 2017). 114 patients with diabetic foot ulcers who had Type 2 Diabetes mellitus were included in the study those who were not on antibiotics or had non-cultured wounds were not included. Staphylococcus aureus was identified in 46%, E. coli in 28%, Pseudomonas in 6%, Klebsiella in 3.5% and other organisms in 17%. 92% of S. aureus was sensitive to Vancomycin and 67% to Clindamycin. Amongst E. coli, 81% showed sensitivity to Imipenem, 69% to Aminoglycosides and 31% to Quinolones. Regarding risk factors 44 percent of patients had peripheral vascular

disease 94 percent had sensory neuropathy and 65 percent had poor glycemic control. In diabetic foot ulcers the study found that adjusting antimicrobial therapy according to susceptibility patterns—for example employing Imipenem for Gram-negative organisms and vancomycin for Gram-positive ones could lower morbidity and stop the emergence of multidrug-resistant infections.

In an Algerian study, (Bouharkat et al., 2020) carried out retrospective study to describe the bacterial ecology and mechanisms of antibiotic resistance in diabetic foot infections (DFIs). Methicillin-resistant Staphylococcus aureus (MRSA) Penicillinase extended-spectrum β-lactamase (ESBL) production and efflux pump overexpression were among the resistance mechanisms examined in the analysis of 117 bacterial strains from DFI patients. Gram-negative bacteria were found to be highly prevalent in the study (61 percent) with Pseudomonas aeruginosa, Escherichia coli and other Enterobacteriaceae being the most common isolates. Of the isolates that were Gram-positive, 39% were Staphylococcus aureus. Prominently, 93 percent of Enterobacteriaceae exhibited resistance to at least one β-lactam antibiotic while a sizable fraction of Staphylococci exhibited resistance to tetracycline (71 percent) and penicillin G (93 percent). Additionally, 18% of S. aureus strains were methicillin-resistant and 43% of Enterobacteriaceae produced ESBL. In more than half of the Gram-negative bacteria that did not ferment efflux pumps were overexpressed. Widespread multidrug resistance was found in the results especially in Acinetobacter Baumannii, Staphylococci and Enterobacteriaceae. This underscores the importance of giving careful thought to empirical antibiotic therapy for DFIs.

A study to evaluate the bacteriological profile and antibiotic susceptibility patterns in patients with diabetic foot infections (DFIs) was conducted. The retrospective cross-sectional study reviewed medical records from the Surgery Department of Ribat University Hospital, analyzing data from September 2017 to February 2019. Out of 250 patients, the majority were male (73.2%) and had type 2 diabetes (86.4%), with most having diabetes for over 10 years. Single microorganism infections were found in 64.7% of cases and mixed infections in 35.3% of cases, according to bacterial cultures. Gram-negative bacteria were more common than Gram-positive ones among the 335 bacterial isolates that were found. The most predominant isolates were Proteus spp., Staphylococcus aureus, and Escherichia coli. The most effective drugs, according to

antibiotic susceptibility testing, were Imipenem, amikacin, and vancomycin. all isolates, however, demonstrated total resistance to different Cephalosporin's. These results highlight the variety of bacterial resistance and the significance of focused antibiotic treatment for patients with DFI (Hamid et al., 2020).

In a study by (Boschetti et al., 2021), from Italy. A retrospective epidemiological study was conducted in 2021 to examine the bacterial species identified from outpatients with diabetic foot infections (DFIs) over a one-year period at a specialist diabetic foot hospital. The study found that the most prevalent pathogens were Staphylococcus aureus and Pseudomonas aeruginosa, which accounted for 13% and 11% of cases, respectively. Methicillin-resistant Staphylococcus aureus (MRSA) was identified from 13% of patients, and 4% of those individuals were resistant to three or more antibiotic classes. Pseudomonas aeruginosa showed considerable fluoroquinolone resistance (57.3 percent), Carbapenem resistance (23.5 percent), and piperacillin resistance (17.6 percent). Other noteworthy pathogens included vancomycin-resistant Enterococcus Faecium (VRE), Morganella Morganii, and Escherichia coli that produce extended-spectrum beta-lactamases (ESBL) and methicillin-resistant Staphylococcus epidermidis. The study underscores how DFI bacteria exhibit complicated resistance patterns, requiring caution when formulating antibiotic treatment programs.

The microbiological profile of diabetic foot ulcers (DFUs) and patterns of antibiotic resistance, with a focus on the various illness severity classes. In order to gather deep tissue specimens for aerobic and anaerobic cultures as well as antimicrobial susceptibility testing, 115 patients underwent needle aspiration and biopsy. 222 different microorganisms were isolated and 69.6% of the cases had polymicrobial infections. Staphylococcus species accounted for 64.2% of the isolates which were classified as Gram-positive bacteria (GPB) being the most common (52.2 percent) with Gram-negative bacteria (GNB) accounting for 33.5 percent with Escherichia coli (33.3 percent) dominating this group. According to the Wagner and IDSA classifications the presence of GNB rose with the infection's severity. Staphylococcus aureus isolates showed notable resistance to ciprofloxacin (70 percent) erythromycin (70 percent) and clindamycin (73 percent). With 40 percent of Enterobacteriaceae containing extended-spectrum beta-lactamase (ESBL) genes GNB showed strong resistance to ciprofloxacin and cephalosporins. Resistance genes such as ermA, ermC, and mecA were found in

8.8% 32.33% and 14.7% of S. aureus isolates respectively. According to the results, GPB infections are most frequently isolated from DFUs but GNB infections rise as the severity of the wound worsens (Taki et al., 2022).

Qu et al., 2024 (Qu et al., 2024) carried out a thorough investigation with an emphasis on Asia and China to ascertain the global incidence and antibiotic susceptibility of pathogens in diabetic foot infections (DFIs). They examined 245 papers with 38,744 patients and 41,427 isolated microorganisms that were published between January 2000 and December 2020. The findings showed that DFI pathogens differed by location and time. While Gram-negative bacteria have become more common over time, the incidence of Gram-positive bacteria has declined. Geographically, Asia reported the lowest incidence of Gram-negative bacteria (44.82%), while America had the highest incidence (62.74%). At 26, 90 percent methicillin-resistant Staphylococcus aureus (MRSA) was most common in Africa. Gram-negative aerobic bacteria were found to be more common in Asia (49.36%), with Escherichia coli and Enterobacter spp. showing the highest rates of prevalence. specifically, in China and Southeast Asia, and Pseudomonas aeruginosa (11.08%. Gram-negative aerobes were best treated with Cefoperazone-Sulbactam and Imipenem, while linezolid, vancomycin, and Teicoplanin were the most effective antibiotics against Gram-positive aerobes.

Aviatin et al., 2023 (Aviatin et al., 2023) evaluated the short-term effects on clinical improvement and the appropriateness of antibiotic use in patients with diabetic foot infections (DFIs) through a retrospective cohort study. The study examined secondary data collected from January 1, 2018, to May 31, 2020, from DFI inpatients at Dr. Cipto Mangunkusumo Hospital in Indonesia. The appropriateness of antibiotic therapy in adult patients with type 2 diabetes mellitus (T2DM) was assessed using the Gyssens algorithm. Of the 178 patients in the study, 113 were eligible subjects. Of them, 94% had a history of complications. 22%had an amputation in the past 60 percent had uncontrolled hyperglycemia. 51% had type 2 diabetes for ten years, and 72% had ulcers graded ≥3. The findings showed that, in accordance with the Gyssens algorithm, 54.0% of patients received the proper antibiotic treatment. This difference was not statistically significant (P = 0.079) even though the clinical improvement rate was higher in the appropriate antibiotic group (60.7%) than in the inappropriate group (42.3%). After adjusting for covariates, multivariate analysis showed that appropriate antibiotic use

was linked to a significant increase in clinical improvement with an adjusted odds ratio of 2.616 (95% CI: 1.117-6.126, P = 0.027) between appropriate and inappropriate use. This implies that patient outcomes in DFIs may be improved by adhering to antibiotic use guidelines.

1.7 Summary

The most frequent pathogens associated with diabetic foot infections (DFIs) are Pseudomonas aeruginosa, Enterobacter spp., Escherichia coli and Staphylococcus aureus. Different antibiotic resistance patterns are shown by these pathogens. For instance, significant resistance to ciprofloxacin erythromycin and clindamycin was demonstrated by Staphylococcus aureus isolates. Methicillin resistance in Staphylococcus species was also highly prevalent. Pseudomonas aeruginosa and Escherichia coli both demonstrated resistance to specific antibiotics and extended-spectrum beta-lactamase (ESBL). For DFI patients targeted and individualized antibiotic therapy is crucial due to the resistance patterns of these pathogens.

Different studies show different prevalence rates of Gram-positive and Gram-negative bacteria in diabetic foot ulcers. Nevertheless, staphylococcus species are the most prevalent gram positive bacteria found in diabetic foot ulcers. Antibiotic susceptibility profile for these bacteria show that Staphylococcus aureus isolates are resistant to antibiotics like methicillin, penicillin G and tetracycline. However, bacteria that are categorized as Gram-negative such as Escherichia coli and Pseudomonas aeruginosa show resistance to antibiotics like fluoroquinolones and extended-spectrum beta-lactamases (ESBL). These findings emphasize the importance of tailored antibiotic treatment regimens based on local microbial profiles and resistance patterns, as well as the growing difficulty of treating DFIs as antibiotic resistance rises.

Patterns of bacterial resistance in diabetic foot infection (DFI) vary by geographic location. One such study, carried out by Aviatin et al. (2023) found that methicillin-resistant Staphylococcus aureus (MRSA) was more common in Africa, whereas Gram-negative aerobic bacteria were more common in Asia. Addition;2ally, a research by Qu and colleagues (2024) showed that DFI pathogens differed by location and time, with the frequency of Gram-negative bacteria rising with time and the incidence of Gram-positive bacteria decreasing. These geographical variations in resistance patterns will

have a substantial influence on antibiotic treatment. They emphasize the necessity of specialized therapy techniques for the proper management of DFIs. Understanding the microbiological composition and local resistance patterns is necessary for effective empirical therapy. To reduce morbidity and arrest the progression of multidrug-resistant infections, antibiotic therapy must be adjusted to susceptibility patterns, such as employing separate antibiotic for Gram-positive and Gram-negative pathogens. Therefore, clinicians must consider regional resistance tendencies when developing antibiotic therapy regimens for DFIs.

Chapter Two

Methodology

2.1 Study Design

A retrospective design was used to investigate the bacterial profile and antibiotic sensitivity patterns of patients with infected diabetic foot ulcers (DFU). The data was taken between the first of January and the end of March 2025.

2.2 Setting

The study was carried out at Salfeet governmental hospital.

2.3 Sample Size

The files of all patients who achieved the inclusion criteria over the prior three years were included.

2.4 Eligibility Criteria

Inclusion Criteria

- Patients diagnosed with infected diabetic foot.
- Patients admitted to Salfeet Hospital between January 2021 and June 2024.
- Patients presented with type 2 diabetes mellitus (T2DM).
- Patients in which wound swab cx taken by specialized doctors (General Surgeons & orthopedic surgeons).

Exclusion Criteria

- Type 1 diabetic patients.
- Patients with incomplete medical records.
- Patients with inappropriate swab cx taken by general practitioners.

2.5 Definitions

Infected Diabetic Foot: defined as an infection of the tissues that make up a diabetic patient's foot, whether confirmed or suspected. A slight skin breakdown can introduce an infection into the generally sterile soft tissues of the foot, leading to diabetic foot infections. A diabetic foot infection might be minor, typically confined to the skin's outermost layers, moderate, extending to the foot's soft tissues, or severe, linked to metabolic instability or systemic toxicity (Noor et al., 2017).

Bacterial Profile: includes the different types of bacteria, their frequency, and their localization, as well as the identification and description of a set or specific bacterial species in an infection or a specific area. The bacterial profile is highly helpful when it comes to diseases like diabetic foot because it provides information on the bacteria causing these illnesses that is needed for diagnosis or treatment (Singh et al., 2005).

Antibiotic Susceptibility Patterns: refer to how different bacterial strains respond to the antibiotics that are used, or, to put it another way, which drugs work best to stop or eradicate the specific bacteria. Both laboratory tests—the broth dilution method and the disc diffusion method—are used to identify this pattern, which shows whether the bacteria are resistant, sensitive, or respond in an intermediate way to a certain antibiotic. It guides treatment decisions by highlighting patients who benefit from antibiotic administration, hence reducing resistance (Petchiappan and Chatterji, 2017).

2.6 Data Collection Method

Data was gathered from the hospital’s electronic medical records. A structured data collection form to extract data from the medical records was used.

Data included demographic information, clinical characteristics, laboratory findings, bacterial cultures, antibiotic susceptibility results, treatment regimens, and patient outcomes.

2.7 Data Collection Tools

A structured data collection form was developed (Appendix A), including the following sections:

Section A: Demographic Information

- Patient file number.
- Age.
- Gender.
- Duration of Diabetes Mellitus.
- Comorbidities (e.g., hypertension, cardiovascular disease).

Section B: Clinical Characteristics

- Ulcer grade, and ischemia grade.
- Presence of neuropathy or peripheral vascular disease.

Section C: Laboratory Findings

- Type of bacterial isolate(s) identified.
- Antibiotic susceptibility results (using standard susceptibility testing methods).

Section D: Treatment and Outcomes

- Antibiotic treatment regimen.
- Other treatments and procedures (according to the diabetic foot care protocol in the hospital)
- Length of hospital stay.
- Outcomes (wound healing or amputation).

In the data collection we included information about the treatment protocol which was applied to the patient as they have the following protocol in the hospital.

2.8 Diabetic Foot Care Protocol in Salfeet Hospital

- Objective: To promote healing and prevent complications in diabetic foot patients through a comprehensive care approach.

1. Initial Assessment

- Perform a thorough examination of the foot to identify wounds, necrotic tissues, and
- signs of infection.
- Assess the patient's history, including diabetes management and previous foot problems.

2. Wound Care

- Situs Bath.
- Use a saline solution with iodine solution for cleansing the wound.
- Daily Dressing.
- Change dressings daily to maintain a clean environment for healing.
- Apply a local ointment over the wound, such as:
- Flaminal Gel: Promotes healing and provides a moist wound environment.
- Procutase Gel: Supports healing through its enzymatic properties.
- Use advanced wound care products like Farmactive patches, which contain materials that promote wound healing.
- Debridement.
- Perform daily debridement, when necessary, especially for wounds with necrotic tissue.
- In cases of severe necrosis, consider surgical options (e.g., ray amputation for toes or forefoot amputation for multiple toes with wet gangrene).

3. Antibiotic Therapy

- Initial Antibiotic Selection.
- Administer Rocephin (ceftriaxone) and Flagyl (metronidazole) upon admission, particularly after taking a swab culture from the infected wound or ulcer.
- Adjusting Antibiotic Therapy.
- Once culture and sensitivity results are obtained, modify the antibiotic regimen based on the identified pathogens.
- Consider multi-resistant organisms when making antibiotic choices and adjust accordingly.

4. Surgical Intervention.

Evaluate the need for amputation in cases where necrotic tissue is present and infection is unmanageable with antibiotics alone.

- Amputation options.
- Ray Amputation: For isolated toe infections.
- Forefoot Amputation: For infections involving multiple toes with wet necrosis.
- Below Knee Amputation: for infections that involving entire foot with heel with poor blood supply.

5. Patient Education.

- Educate patients on proper foot care, including daily inspections and diabetes
- management.
- Encourage adherence to treatment plans, including medication and wound care regimens.
- Discuss lifestyle changes to improve glycemic control and prevent future complications.

2.9 Study Variables

Dependent Variables.

- Bacterial profile: types of bacteria that cause DFI.
- Antibiotic susceptibility patterns: The efficiency of different antibiotics against the isolated bacteria (sensitive, intermediate, or resistant) is known as the antibiotic susceptibility patterns.

Independent Variables.

- Demographics profile for patients as: age, gender.
- Clinical characteristics: duration of diabetes, comorbidities (such as cardiovascular disease, kidney damage, etc.), and diabetic foot severity.

2.10 Data Analysis

Data was analyzed using Statistical Package for Social Sciences (SPSS) software.

Descriptive statistics (mean, standard deviation, frequency, and percentage) were computed for demographic and clinical characteristics.

Bacterial profiles were categorized based on species identification and resistance patterns.

Antibiotic susceptibility patterns were analyzed to determine the most effective treatment options.

Categorical variables were compared using the Chi square test or Fisher test as appropriate. A p-value of less than 0.05 was considered to be statistically significant for all analyses.

2.11 Ethical Consideration

The following permissions were obtained.

Institutional Review Board (IRB) Acceptance: The Institutional Review Board (IRB) of Al-Najah National University granted ethical approval prior to starting the study (Appendix B).

Ministry of Health Approval: In order to facilitate access to the data that the researcher needs to achieve the objectives of the study, MOH approval was obtained (Appendix C).

Chapter Three

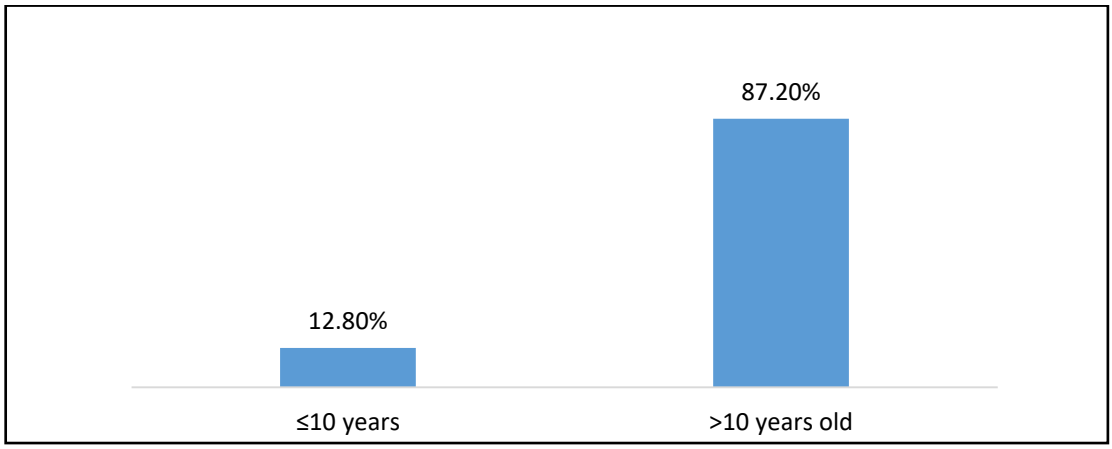
Results

3.1 Demographic and clinical characteristics of the patients

The study included 211 participants, with the majority (45.0%) aged between 50-59 years, followed by 26.1% aged 60-69 years, 19% aged 40-49 years, and 10% above 69 years. Regarding diabetes mellitus (DM) duration, most participants (87.2%) had been diagnosed for more than 10 years, whereas 12.8% had been diagnosed within the last 10 years. As seen in Figure 3.

Figure 3

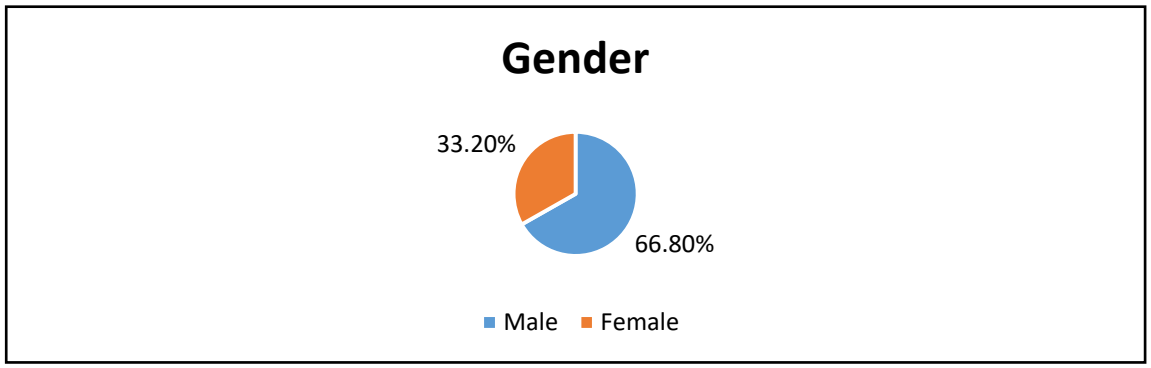
Time since diagnosed with diabetes mellitus



Regarding gender of patients: The Males comprised 66.8% of the sample, while females accounted for 33.2%. As in Figure 4

Figure 4

Gender distribution of diabetic patients



In terms of medical history, hypertension (HTN) and cardiovascular diseases (CVD) were the most common comorbidities, affecting 54.0% of the participants. Neuropathy was present in 34.6%, nephropathy in 24.6%, and angiopathy in 8.5% of the study population (Table 1 and Figure 5).

Figure 5

Age distribution of the patients

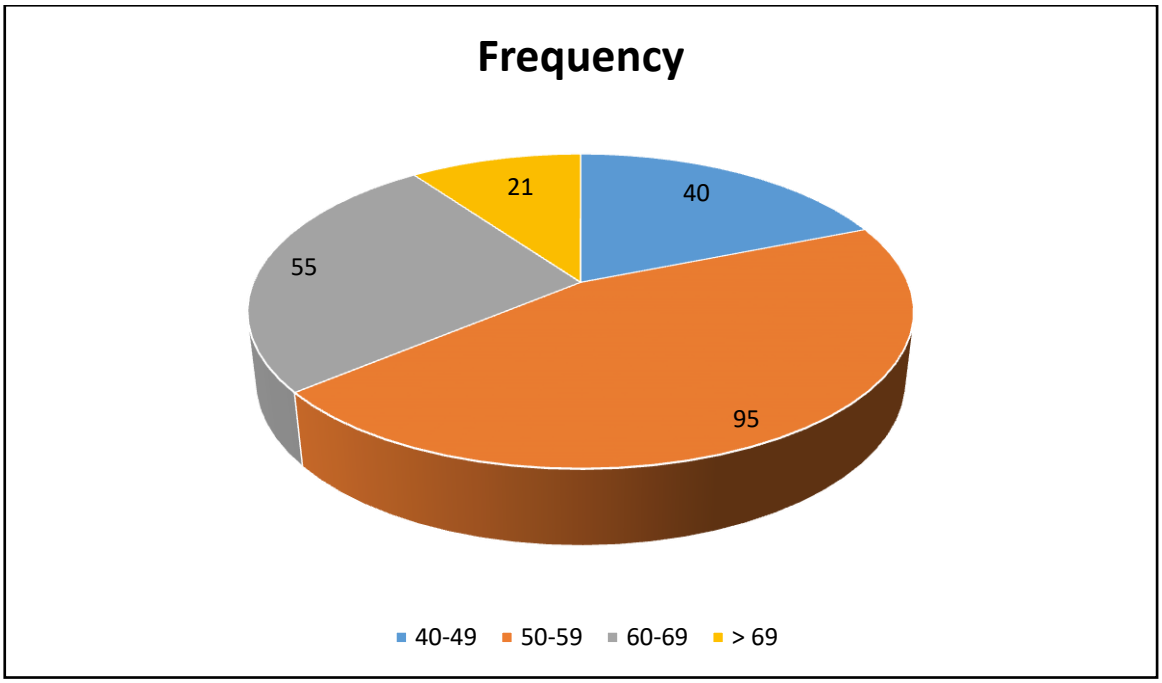


Figure 6

Clinical characteristics of the diabetic patients

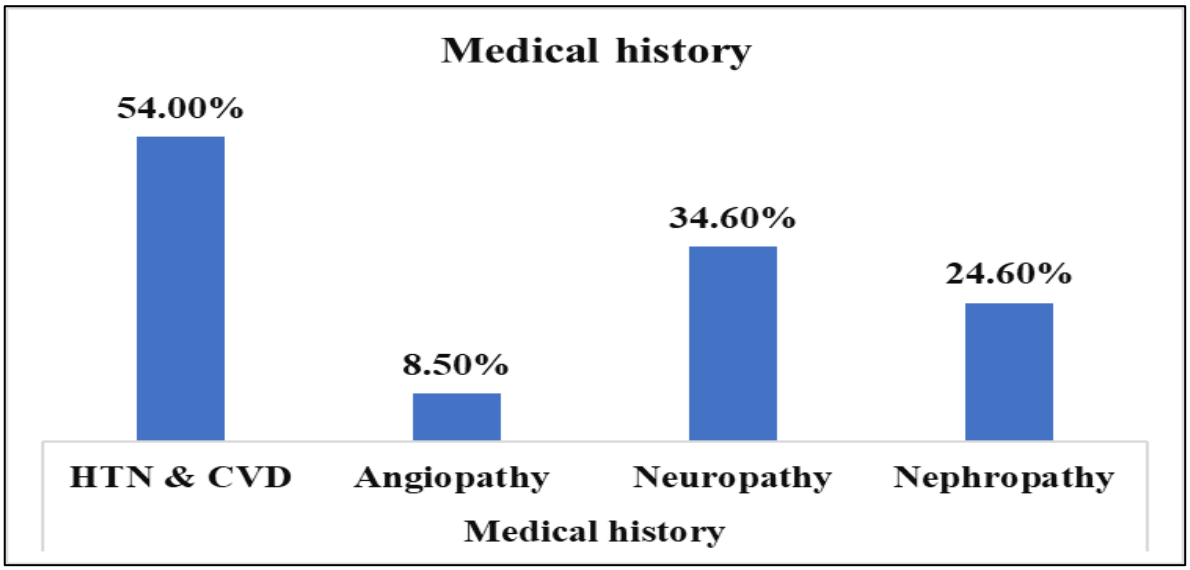


Table 1

Demographic and clinical characteristics of the patients

Demographic variables		N	%
Age	40-49 years	40	19.0%
	50-59 years	95	45.0%
	60 – 69 years	55	26.1%
	>69 years	21	10.0%
Gender	Male	141	66.8%
	Female	70	33.2%
Diagnosed with DM	≤10 years	27	12.8%
	>10 years old	184	87.2%
Medical history	HTN & CVD	114	54.0%
	Angiopathy	18	8.5%
	Neuropathy	73	34.6%
	Nephropathy	52	24.6%

3.2 Diabetic foot infection characteristics

Among the study participants, the most common ulcer site was the forefoot (33.1%), followed by the base of the big toe at the metatarsophalangeal (MTP) joint (28.0%), the base of the fifth toe at the MTP joint (19.7%), the big toe (12.6%), and the heel (6.6%).

Regarding the grade of diabetic foot ulcers, 42.2% had ulcers extending to the tendon or capsule (Grade C), while 30.3% had superficial ulcers involving only the skin (Grade B). Ulcers penetrating to the bone (Grade D) were present in 20.4% of cases, and 7.1% had ulcers with osteomyelitis or abscess (Grade E).

In terms of ulcer staging based on infection and ischemia, the majority (41.2%) had ischemia, with or without infection (Stage 3), while 31.8% had both infection and ischemia (Stage 4). Infection without ischemia (Stage 2) was present in 27.0% of cases. As seen in (Table 2**)**.

Table 2

Frequencies and percentages of the site, grade and stage of ulcer (n=211)

		n	%
Site	Forefoot	70	33.1%
	base of big toe MTP joint	59	28.0%
	Base of 5th toe MTP joint	42	19.7%
	Big toe	27	12.6%
	Heel	13	6.6%
Grade of diabetic foot ulcer	B: superficial ulcer; skin involved	64	30.3%
	C: ulcer extending to tendon or capsule	89	42.2%
	D: ulcer penetrating to bone	43	20.4%
	E: ulcer with osteomyelitis or abscess	15	7.1%
Stage of diabetic foot ulcer based on presence of infection and ischemia	Stage 2: infection present, no ischemic	57	27.0%
	Stage 3: ischemic present, with or without infection	87	41.2%
	Stage 4: both infection and ischemia present	67	31.8%

3.3 Association between ulcer grade and HgA1C level

Glycosylated hemoglobin (HgA1C) level was measured at the date of admission for only 120 patients. For those patients, a chi-square test was used to investigate the association between the severity of diabetic foot ulcers and HgA1C, which reflects blood sugar control; patients were divided into 4 groups according to level of HgA1C, including group 1: ≤ 7.5%, group 2: 7.6-8.5%, group 3: 8.6-9.5%, and group 4: > 9.5%. A significantly higher proportion of patients with ulcer grade E had HgA1C readings >9.5, and 87.5% of patients with ulcer grade D had A1C readings between 8.6 and 9.5. These findings highlight that higher HgA1C levels are associated with an increased foot ulceration grade (p-value <0.001). As in Table 3.

Table 3

Association between ulcer grade and HgA1C level (n = 120)

HgA1C	Grade B	Grade C	Grade D	Grade E	P-value
≤ 7.5	25 (69.4%)	9 (25.0%)	2 (5.6%)	0 (0.0%)	<0.001
7.6-8.5	11 (21.6%)	40 (78.4%)	0 (0.0%)	0 (0.0%)	
8.6-9.5	0 (0.0%)	1 (4.2%)	21 (87.5%)	2 (8.3%)	
>9.5	0 (0.0%)	1 (11.1%)	1 (11.1%)	7 (77.8%)	

3.4 Diabetic foot infections treatment and outcomes

Among the 211 patients with diabetic foot infections, the majority (52.6%) underwent debridement of necrotic tissues combined with IV antibiotics and daily dressing as part of their management. IV antibiotics, along with local dressing creams such as Farmactive hydrogel, local antibiotic creams, or skin patches, were used in 34.6% of

cases. Amputation, including RAY amputation, forefoot amputation, or below-knee amputation, was required in 12.8% of cases. For the rest of the patients **(**87.2%), fortunately, the ulcer healed with no need for amputation (Table 4).

Table 4

Diabetic foot infections treatment and outcomes

Management	n	%
IV antibiotics, with local dressing creams like: Farmactive hydrogel, local antibiotics cream, or skin patches.	73	34.6%
Debridement of necrotic tissues with IV antibiotics and daily dressing.	111	52.6%
IV antibiotics with amputation: RAY amputation, forefoot amputation or Below knee amputation.	27	12.8%

3.5 Microorganisms isolated from diabetic foot ulcers

The most commonly isolated microorganism was Escherichia coli, detected in 26.5% of cases, followed by Staphylococcus aureus (20.9%) and Pseudomonas aeruginosa (10.9%). Klebsiella pneumoniae and Acinetobacter spp. were found in 8.1% and 8.5% of cases, respectively.

Methicillin-resistant Staphylococcus aureus (MRSA) was present in 7.6% of cases, while Staphylococcus epidermidis and Enterococcus spp. were each found in 3.8% of samples. Less commonly, Morganella Morganii (2.4%), Enterobacter spp. (1.4%), and Providencia Stuartii (0.5%) were detected.

Polymicrobial infections were identified in a few cases, including Escherichia coli with Klebsiella pneumoniae (0.5%), Pseudomonas aeruginosa with MRSA (1.4%), Escherichia coli with Pseudomonas aeruginosa (0.9%), and Escherichia coli with Staphylococcus aureus (0.9%). Clostridium and Acinetobacter were each isolated in 0.9% of cases (Table 5).

Table 5

Frequencies and percentages of microorganisms isolated

		n	%
Microorganism	Escherichia coli	56	26.5%
	Staphylococcus aureus	44	20.9%
	Clostridium	2	0.9%
	Pseudomonas aeruginosa	23	10.9%
	Escherichia coli + Klebsiella pneumoniae	1	0.5%
	Pseudomonas aeruginosa + MRSA	3	1.4%
	Morganella Morganii	5	2.4%
	Staphylococcus epidermidis	8	3.8%
	Acinetobacter	2	0.9%
	Enterococcus spp.	8	3.8%
	Klebsiella pneumoniae	17	8.1%
	Acinetobacter spp.	18	8.5%
	Escherichia coli + Pseudomonas	2	0.9%
	Escherichia coli + Staphylococcus aureus	2	0.9%
	Methicillin-resistant Staphylococcus aureus (MRSA)	16	7.6%
	Enterobacter spp	3	1.4%
	Providencia Stuartii	1	0.5%

3.6 Antibiotic sensitivity patterns

Among the antibiotics tested for sensitivity, Meropenem/Ertapenem showed the highest sensitivity, with 63.03%, followed by Amikacin at 47.39%. Gentamycin (40.28%), Piperacillin + Tazobactam (39.81%), Ciprofloxacin/Levofloxacin (38.86%), and Cephalosporins (3rd generation group) (38.39%) also demonstrated notable sensitivity rates.

Other antibiotics with moderate sensitivity included Vancomycin (26.54%), Clindamycin (25.12%), and Tetracycline/Doxycycline (20.85%). Amoxicillin + Clavulanic acid showed the lowest sensitivity, at only 3.79%, as seen in table 6.

Table 6

Frequencies and percentages of antibiotic sensitivity (n=211)

	Sensitive		Resistance	
Antibiotics	N	%	n	%
Amikacin	100	47.39%	111	52.61%
Amoxicillin + Clavulanic acid	8	3.79%	203	96.21%
Cephalosporin's (3rd generation)	81	38.39%	130	61.61%
Ciprofloxacin / Levofloxacin	82	38.86%	129	61.14%
Tetracycline / Doxycycline	44	20.85%	167	79.15%
Gentamycin	85	40.28%	126	59.72%
Meropenem / Ertapenem	133	63.03%	78	36.97%
Piperacillin + Tazobactam	84	39.81%	127	60.19%
Clindamycin	53	25.12%	158	74.88%
Vancomycin	56	26.54%	155	73.46%

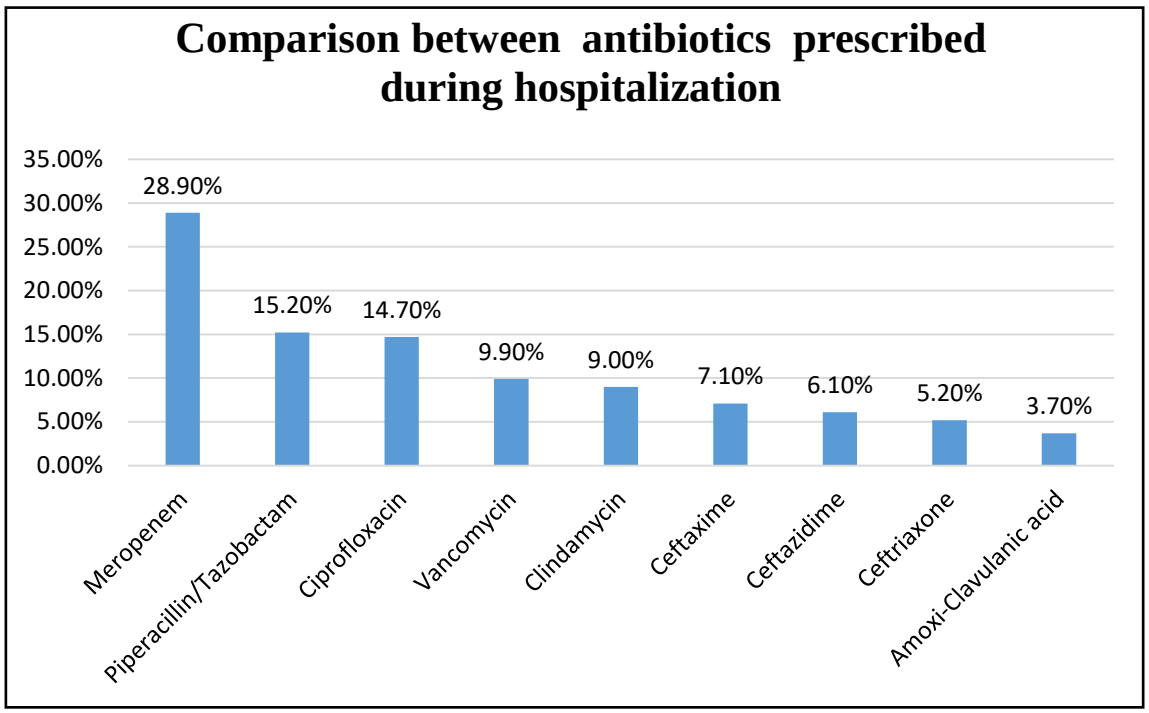
3.7 Antibiotics prescribed during hospital stay

The chart illustrates the types of antibiotics administered to patients based on hospital stay duration. Meropenem was the most frequently used antibiotic, prescribed to 28.9% of patients. This was followed by: Piperacillin/Tazobactam (15.2%) and Ciprofloxacin (14.7%).

Other commonly used antibiotics included Vancomycin (9.9%) and Clindamycin (9.0%). Less frequently used antibiotics were Ceftaxime (7.1%), Ceftazidime (6.1%), and Ceftriaxone (5.2%), while Amoxicillin-clavulanic acid was the least commonly used, given to only 3.7% of patients. These findings suggest that broad-spectrum antibiotics, especially Meropenem, were preferred in the management of patients requiring hospitalization, likely due to the severity or resistance profile of infections (Figure 7).

Figure 7

Antibiotics prescribed during hospitalization



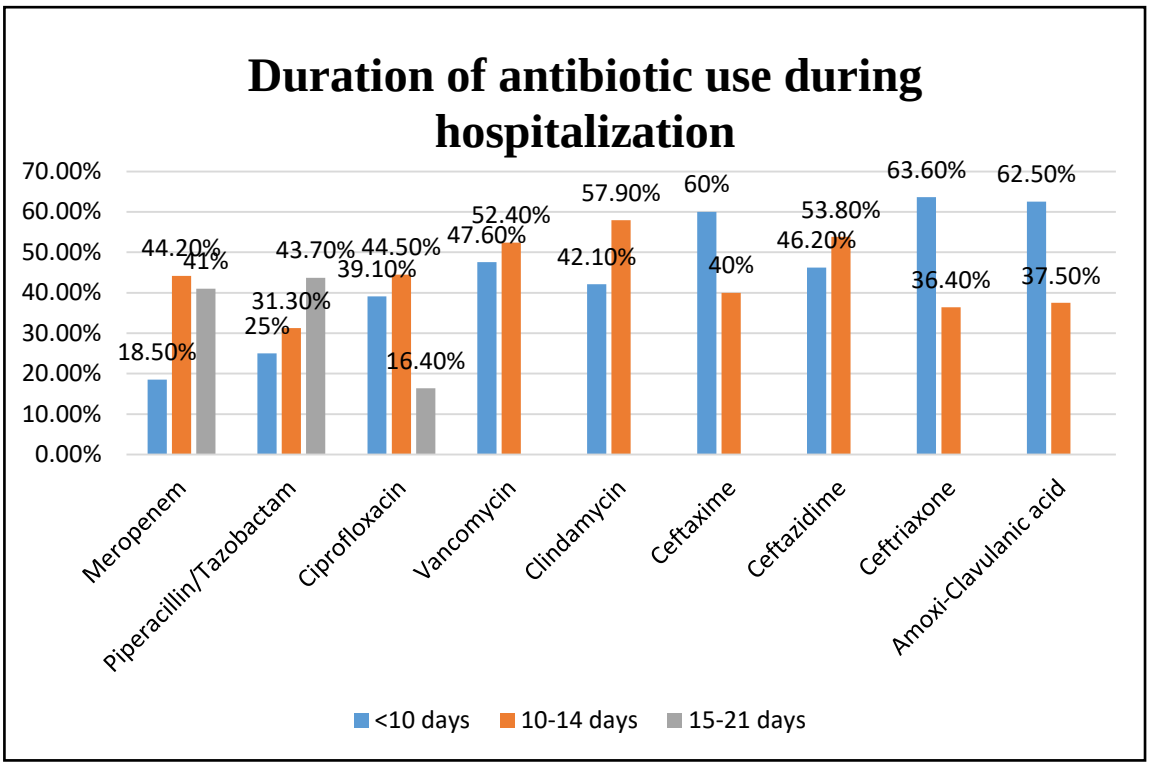
3.8 Duration of antibiotics management in days during hospital stay

Regarding duration of hospital stay, 75 patients were hospitalized for < 10 days, 83 for 10-14 days and 53 for 15-21 days, duration of hospital stay was associated significantly with ulcer grade as patients with grade D and E were 12 (16%) of patients who stayed < 10 days while they were 18 (34.0%) among those who stayed 15-21 days (p-value = 0.004).

The chart illustrates the duration of antibiotic management during hospital stays, categorized into three-time frames: less than 10 days, 10–14 days, and 15–21 days. The use of Ceftriaxone (63.6%), Ceftaxime (60.0%), and Amoxicillin-clavulanic acid (62.5%) was most common in patients hospitalized for less than 10 days, indicating their association with shorter treatment durations and milder cases. On the other hand, Meropenem and piperacillin / Tazobactam were more frequently used in patients with longer stays, with 41% and 43.7% of cases, respectively, involving 15–21 days of treatment. Vancomycin and Ciprofloxacin showed a relatively balanced distribution across all durations. Clindamycin was most commonly used in the 10–14-day range (57.9%), while Ceftazidime showed moderate use across both short and medium durations (Figure 8).

Figure 8

Duration of antibiotics management in days during hospital stay



3.9 Association between ulcer grade and medical history

A chi-square test was used to investigate the association between the severity of diabetic foot ulcers and medical history factors, including hypertension (HTN), cardiovascular disease (CVD), angiopathy, neuropathy, and nephropathy.

Hypertension (HTN) and CVD: There was no significant association between HTN and CVD and ulcer grade ($\chi^2 = 1.738$, $p = 0.628$).

Angiopathy: The association between angiopathy and ulcer grade was not statistically significant ($\chi^2 = 6.93$, $p = 0.074$).

Neuropathy: No significant relationship was observed between neuropathy and ulcer grade ($\chi^2 = 6.847$, $p = 0.077$).

Nephropathy: A statistically significant association was found between nephropathy and ulcer grade ($\chi^2 = 11.979$, $p = 0.007$). Individuals with nephropathy had a higher prevalence of more severe ulcers, particularly Grade D (34.6%) and Grade E (7.7%), compared to those without nephropathy.

These results indicate that among the medical history variables analyzed, only nephropathy was significantly associated with the severity of diabetic foot ulcers (Table 7).

Table 7

Association between grade of ulcer and medical history

Grade	Medical history HTN & CVD				X2	P-value
	No		Yes			
	N	%	n	%		
B: superficial ulcer; skin involved	33	34.0%	31	27.2%	1.738	.628
C: ulcer extending to tendon or capsule	41	42.3%	48	42.1%		
D: ulcer penetrating to bone	17	17.5%	26	22.8%		
E: ulcer with osteomyelitis or abscess	6	6.2%	9	7.9%		
	Angiopathy				X2	P-value
	No		Yes			
	N	%	n	%		
B: superficial ulcer; skin involved	60	31.1%	4	22.2%	6.93	.074
C: ulcer extending to tendon or capsule	82	42.5%	7	38.9%		
D: ulcer penetrating to bone	40	20.7%	3	16.7%		
E: ulcer with osteomyelitis or abscess	11	5.7%	4	22.2%		
	Neuropathy				X2	P-value
	No		Yes			
	N	%	n	%		
B: superficial ulcer; skin involved	45	32.6%	19	26.0%	6.847	.077
C: ulcer extending to tendon or capsule	63	45.7%	26	35.6%		
D: ulcer penetrating to bone	23	16.7%	20	27.4%		
E: ulcer with osteomyelitis or abscess	7	5.1%	8	11.0%		
	Nephropathy				X2	P-value
	No		Yes			
	N	%	n	%		
B: superficial ulcer; skin involved	56	35.2%	8	15.4%	11.979	.007*
C: ulcer extending to tendon or capsule	67	42.1%	22	42.3%		
D: ulcer penetrating to bone	25	15.7%	18	34.6%		
E: ulcer with osteomyelitis or abscess	11	6.9%	4	7.7%		

Chi-square test

*significant at ≤0.05

3.10 Association between microorganism and antibiotics

When the sensitivity against the top five common bacteria was evaluated for the most commonly used antibiotics, Meropenem showed the best sensitivity for gram negative bacteria, amikacin and gentamycin showed better sensitivity for gram negative bacteria also, Piperacillin + Tazobactam showed accepted sensitivity with gram negative bacteria and a very low sensitivity with Staph spp., the sensitivity to quinolones was moderate in general (Table 8).

Table 8

Antibiotic sensitivity to commonly isolated pathogens

	Antibiotic		Meropenem/ Ertapenem <0.001		Amikacin <0.001		Gentamycin 0.080		Piperacillin +Tazobactam <0.001		Ciprofloxacin /Levofloxacin 0.386	
	Microorganism	Total	n	%	n	%	n	%	n	%	n	%
1	Escherichia coli	56	52	92.9%	34	60.7%	22	39.3%	29	51.8%	20	35.7%
2	Staphylococcus aureus	44	12	27.3%	10	22.7%	24	54.5%	3	6.8%	18	40.9%
3	Pseudomonas aeruginosa	23	19	82.6%	14	60.9%	8	34.8%	15	65.2%	10	43.5%
4	Acinetobacter spp.	18	18	100.0%	11	61.1%	3	16.7%	12	66.7%	5	27.8%
5	Klebsiella pneumoniae	17	13	76.5%	12	70.6%	7	41.2%	8	47.1%	10	58.8%
6	Methicillin-resistant Staph aureus (MRSA)	16	1	6.3%	1	6.3%	7	43.8%	1	6.3%	3	18.8%

The findings highlight Meropenem/Ertapenem as highly effective against Escherichia coli and moderately effective against Pseudomonas aeruginosa and Acinetobacter spp., while demonstrating limited efficacy against Staphylococcus aureus and MRSA in diabetic foot infections. A chi-square test revealed a statistically significant association between Escherichia coli and meropenem/Ertapenem sensitivity ($\chi^2 = 106.247$, $p < 0.001$). A significantly higher proportion of Escherichia coli isolates (39.1%) were sensitive to meropenem/Ertapenem, while only 5.1% were resistant, indicating strong effectiveness of these antibiotics against this pathogen. In contrast, Staphylococcus aureus exhibited a much lower sensitivity rate (9.0%) relative to its resistance (41.0%), indicating that meropenem/Ertapenem are ineffective against this pathogen. Likewise, Methicillin-resistant Staphylococcus aureus (MRSA) demonstrated significant resistance, exhibiting just 0.8% sensitivity (Table 9).

Table 9

Association between Meropenem / Ertapenem sensitivity and microorganisms

Microorganism	Meropenem / Ertapenem				X2	P-value
	No		Yes			
	N	%	n	%		
Escherichia coli	4	5.1%	52	39.1%	106.247	<0.001*
Staphylococcus aureus	32	41.0%	12	9.0%		
Clostridium	2	2.6%	0	0.0%		
Pseudomonas aeruginosa	4	5.1%	19	14.3%		
Escherichia coli + Klebsiella pneumoniae	0	0.0%	1	0.8%		
Pseudomonas aeruginosa + MRSA	2	2.6%	1	0.8%		
Morganella Morganii	0	0.0%	5	3.8%		
Staphylococcus epidermidis	6	7.7%	2	1.5%		
Acinetobacter	1	1.3%	1	0.8%		
Enterococcus spp.	6	7.7%	2	1.5%		
Klebsiella pneumoniae	4	5.1%	13	9.8%		
Acinetobacter spp.	0	0.0%	18	13.5%		
Escherichia coli + Pseudomonas	0	0.0%	2	1.5%		
Escherichia coli + Staphylococcus aureus	1	1.3%	1	0.8%		
Methicillin-resistant Staphylococcus aureus (MRSA)	15	19.2%	1	0.8%		
Enterobacter spp	0	0.0%	3	2.3%		
Providencia Stuartii	1	1.3%	0	0.0%		

These findings highlight that piperacillin + tazobactam is highly effective against Escherichia coli and has moderate efficacy against Pseudomonas aeruginosa and Acinetobacter spp., while being largely ineffective against Staphylococcus aureus and MRSA in diabetic foot infections**.** A chi-square test revealed a statistically significant association between Escherichia coli and piperacillin + tazobactam sensitivity (χ^2 = 66.146, $p < 0.001$). A higher proportion of Escherichia coli isolates (34.5%) were sensitive to piperacillin + tazobactam compared to those that were resistant (21.3%), indicating strong effectiveness of this antibiotic against Escherichia coli. In contrast, Staphylococcus aureus had a significantly low sensitivity rate (3.6%) relative to its resistance (32.3%), indicating that piperacillin + tazobactam is predominantly ineffective against this pathogen. Likewise, Methicillin-resistant Staphylococcus aureus (MRSA) exhibited significant resistance, demonstrating a mere 1.2% susceptibility. Conversely, Pseudomonas aeruginosa and Acinetobacter species (Table 10).

Table 10

Association between Piperacillin + Tazobactam sensitivity and microorganisms

Microorganism	Piperacillin + Tazobactam				X^2	P-value
	No		Yes			
	N	%	n	%		
Escherichia coli	27	21.3%	29	34.5%	66.146	<0.001*
Staphylococcus aureus	41	32.3%	3	3.6%		
Clostridium	2	1.6%	0	0.0%		
Pseudomonas aeruginosa	8	6.3%	15	17.9%		
Escherichia coli + Klebsiella pneumoniae	0	0.0%	1	1.2%		
Pseudomonas aeruginosa + MRSA	2	1.6%	1	1.2%		
Morganella Morganii	0	0.0%	5	6.0%		
Staphylococcus epidermidis	7	5.5%	1	1.2%		
Acinetobacter	1	0.8%	1	1.2%		
Enterococcus spp.	6	4.7%	2	2.4%		
Klebsiella pneumoniae	9	7.1%	8	9.5%		
Acinetobacter spp.	6	4.7%	12	14.3%		
Escherichia coli + Pseudomonas	0	0.0%	2	2.4%		
Escherichia coli + Staphylococcus aureus	2	1.6%	0	0.0%		
Methicillin-resistant Staphylococcus aureus (MRSA)	15	11.8%	1	1.2%		
Enterobacter spp	0	0.0%	3	3.6%		
Providencia Stuartii	1	0.8%	0	0.0%		

A chi-square test revealed a statistically significant association between: Escherichia coli and amikacin sensitivity ($\chi^2 = 49.465$, $p < 0.001$). A higher percentage of Escherichia coli isolates (34.0%) were sensitive to amikacin compared to those that were not (19.8%), indicating a strong susceptibility of this microorganism to the antibiotic. Conversely, Staphylococcus aureus and methicillin-resistant Staphylococcus aureus (MRSA) showed lower sensitivity to amikacin, with only 10.0% and 1.0% of cases being susceptible, respectively. These findings highlight amikacin's effectiveness against Escherichia coli, while its limited activity against Staphylococcus aureus and MRSA suggests the need for alternative treatments for these infections see Table D1 in (Appendix D).

A chi-square test revealed a statistically significant association between Escherichia coli and sensitivity to amoxicillin + clavulanic acid ($\chi^2 = 32.269$, $p = 0.009$). However, the proportion of Escherichia coli isolates sensitive to this antibiotic (25.0%) was nearly identical to those that were not (26.6%), indicating limited effectiveness. Additionally, Morganella Morganii, Acinetobacter spp., Methicillin-resistant Staphylococcus aureus (MRSA), and Providencia Stuartii showed some sensitivity to amoxicillin + clavulanic acid, with 12.5% of cases responding to treatment. Notably, Pseudomonas aeruginosa, Klebsiella pneumoniae, and Staphylococcus epidermidis demonstrated complete resistance. These findings suggest that amoxicillin + clavulanic acid has limited efficacy against most of the isolated microorganisms, necessitating alternative treatment options for diabetic foot infections see Table D2 in (Appendix D).

The chi-square test did not reveal a statistically significant association between any microorganism and cephalosporin sensitivity ($\chi^2 = 19.464$, $p = 0.245$). While Escherichia coli showed a slightly higher proportion of sensitivity (29.6%) compared to resistance (24.6%), the difference was not significant. Similarly, Staphylococcus aureus had a minor increase in sensitivity (23.5%) versus resistance (19.2%). Pseudomonas aeruginosa and Methicillin-resistant Staphylococcus aureus (MRSA) exhibited lower sensitivity rates, indicating reduced effectiveness of cephalosporins against these pathogens. These findings suggest that cephalosporins do not exhibit a strong selective efficacy against the bacterial strains isolated from diabetic foot ulcers see Table D3 in (Appendix D).

The chi-square test did not reveal a statistically significant association between any microorganism and sensitivity to ciprofloxacin/levofloxacin ($\chi^2 = 16.993$, $p = 0.386$). While Escherichia coli showed similar sensitivity (24.4%) and resistance (27.9%) rates, the difference was not significant. Staphylococcus aureus and Pseudomonas aeruginosa also displayed comparable distributions between resistant and sensitive cases. Klebsiella pneumoniae had a slightly higher sensitivity (12.2%) compared to resistance (5.4%), but the association remained insignificant. These findings suggest that ciprofloxacin and levofloxacin do not exhibit a clear selective advantage against the bacterial strains isolated from diabetic foot ulcers see Table D4 in (Appendix D).

A chi-square test revealed a statistically significant association between Escherichia coli and tetracycline/doxycycline sensitivity ($\chi^2 = 72.334$, $p < 0.001$). Escherichia coli showed a markedly low sensitivity rate (4.5%), indicating that it is largely resistant to tetracycline/doxycycline. Conversely, Staphylococcus aureus demonstrated a much higher sensitivity (54.5%) compared to its resistance rate (12.0%), suggesting that tetracycline/doxycycline is effective against this microorganism. Additionally, Methicillin-resistant Staphylococcus aureus (MRSA) exhibited a higher proportion of sensitivity (15.9%) compared to its resistance (5.4%), though at a lower rate than Staphylococcus aureus. Pseudomonas aeruginosa and Klebsiella pneumoniae showed complete resistance to tetracycline/doxycycline, while Staphylococcus epidermidis had a moderate sensitivity rate (9.1%). These findings highlight the limited efficacy of tetracycline/doxycycline against Escherichia coli and Pseudomonas aeruginosa, while suggesting its potential effectiveness against Staphylococcus aureus and MRSA in diabetic foot infections see Table D5 in (Appendix D).

The chi-square test did not reveal a statistically significant association between any microorganism and gentamycin sensitivity ($\chi^2 = 24.434$, $p = 0.080$). While Staphylococcus aureus showed a higher sensitivity rate (28.2%) compared to its resistance (15.9%), and Morganella Morganii exhibited a slight increase in sensitivity (4.7%), these differences were not statistically significant. Similarly, Escherichia coli displayed comparable resistance (27.0%) and sensitivity (25.9%) rates, indicating no strong preference for gentamycin effectiveness. Other microorganisms, including Pseudomonas aeruginosa, Acinetobacter spp., and Methicillin-resistant Staphylococcus aureus (MRSA), showed no notable variations in sensitivity. These findings suggest that

gentamycin does not exhibit a clear selective advantage against the bacterial strains isolated from diabetic foot infections see Table D6 in (Appendix D).

A chi-square test revealed a statistically significant association between Escherichia coli and Staphylococcus aureus with clindamycin sensitivity ($\chi^2 = 121.924$, $p < 0.001$). Escherichia coli exhibited a markedly low sensitivity rate (3.8%) compared to a high resistance rate (34.2%), indicating that clindamycin is largely ineffective against this microorganism. In contrast, Staphylococcus aureus had a markedly greater sensitivity rate (66.0%) relative to its resistance (5.7%), indicating the substantial efficacy of clindamycin against this bacterium. Likewise, Methicillin-resistant Staphylococcus aureus (MRSA) demonstrated moderate sensitivity (11.3%), but resistance remained significant (6.3%). Various pathogens, such as Pseudomonas aeruginosa, Klebsiella pneumoniae, and Acinetobacter spp., exhibited total resistance to clindamycin. These data underscore clindamycin's significant efficacy against Staphylococcus aureus, while demonstrating its limited effectiveness against Escherichia coli, Pseudomonas aeruginosa, and Acinetobacter spp. in diabetic foot infections see Table D7 in (Appendix D).

A chi-square test revealed a statistically significant association between Escherichia coli and Staphylococcus aureus with vancomycin sensitivity ($\chi^2 = 113.045$, $p < 0.001$). Escherichia coli demonstrated an extremely low sensitivity rate (1.8%) compared to a high resistance rate (35.5%), indicating that vancomycin is largely ineffective against this microorganism. In contrast, Staphylococcus aureus had a much greater sensitivity rate (46.4%) relative to its resistance (11.6%), indicating that vancomycin is very efficacious against this bacterium. Likewise, Methicillin-resistant Staphylococcus aureus (MRSA) exhibited significant sensitivity (19.6%), although Staphylococcus epidermidis and Enterococcus spp. had intermediate sensitivity rates (12.5% and 10.7%, respectively).

Other microorganisms, including Pseudomonas aeruginosa, Klebsiella pneumoniae, and Acinetobacter spp., exhibited complete resistance to vancomycin. These findings highlight vancomycin as highly effective against Staphylococcus aureus and moderately effective against MRSA, Staphylococcus epidermidis, and Enterococcus spp., while being largely ineffective against Escherichia coli and other Gram-negative bacteria in diabetic foot infections see Table D8 in (Appendix D).

3.11 Summary

In summary, the analysis revealed significant associations between specific microorganisms and antibiotic sensitivity. Escherichia coli showed high sensitivity to meropenem/Ertapenem ($p < 0.001$) and piperacillin + tazobactam ($p < 0.001$), while demonstrating strong resistance to tetracycline/doxycycline ($p < 0.001$), clindamycin ($p < 0.001$), vancomycin ($p < 0.001$), and amoxicillin + clavulanic acid ($p = 0.009$). Conversely, Staphylococcus aureus exhibited significant sensitivity to clindamycin ($p < 0.001$) and vancomycin ($p < 0.001$), indicating their effectiveness against this pathogen. Methicillin-resistant Staphylococcus aureus (MRSA) displayed moderate sensitivity to clindamycin ($p < 0.001$) and vancomycin ($p < 0.001$), but strong resistance to piperacillin + tazobactam ($p < 0.001$). Pseudomonas aeruginosa showed notable sensitivity to meropenem/Ertapenem ($p < 0.001$) and piperacillin + tazobactam ($p < 0.001$). These findings highlight the efficacy of Carbapenems and beta-lactam/beta-lactamase inhibitors against Escherichia coli and Pseudomonas aeruginosa, while clindamycin and vancomycin are highly effective against Staphylococcus aureus and MRSA, emphasizing the need for targeted antibiotic selection in treating diabetic foot infections. The level of resistance to all antibiotics is high, so treatment guided by culture and sensitivity is very important.

Chapter Four

Discussions and Conclusions

4.1 The site, grade and stage of ulcer among patients

The current study examined the characteristics of diabetic foot infections (DFIs) and found that most patients had diabetic foot ulcers (DFUs) at 74.4%, while diabetic foot gangrene, which involves infection and poor blood flow, made up 25.6%. These findings support recent studies that indicate a significant portion of diabetic's experience severe foot issues.

Our research showed that ulcers were most found on the forefoot (33.1%), especially at important pressure points like the base of the big toe at the metatarsophalangeal (MTP) joint (28.0%) and the fifth toe (19.7%). This distribution is consistent with previous research, which found these anatomical locations to be sensitive owing to increasing plantar pressure and peripheral neuropathy, both of which greatly contribute to ulceration (Boulton et al.)

In terms of DFUs, the study found that 42.2% of ulcers progressed to tendon or capsule (Grade C), therefore suggesting significant tissue involvement. While a lower percentage (7.1%) demonstrated osteomyelitis or abscess development (Grade E), 20.4% of instances revealed ulcers penetrating to the bone (Grade D). Previous studies connecting deeper ulcers with increased risk of sequelae, including osteomyelitis and amputations, underline the significance of ulcer development indicated by our data (Armstrong et al., 1998, Mathioudakis et al., 2017).

Our staging based on ischemia and infection shows 31.8% of patients presented with both infection and ischemia (Stage 4), and 41.2% presented with ischemia, with or without concomitant infection (Stage 3). Consistent with research from European cohorts revealing equally high prevalence rates of concurrent peripheral vascular disease and infections in diabetic foot cases, these phases reflect advanced disease in a considerable proportion of patients (Prompers et al., 2007, Meloni et al., 2020). Clinically, the notable frequency of advanced-stage DFUs and gangrene in our group emphasizes the great need for early identification, fast control of infections, and urgent

vascular intervention. Further validating the need for integrated care models, multidisciplinary team approaches including vascular surgeons, podiatrists, endocrinologists, orthopedists, and infection specialists have shown effectiveness in lowering significant amputation rates and improving general patient outcomes (Armstrong et al., 2023).

In summary, the present work emphasizes the severe character and anatomical distribution of DFIs and supports the need for early, aggressive, and coordinated therapeutic therapy to minimize severe consequences and increase patient prognoses.

4.2 Diabetic foot infections outcomes

In 52.6% of the patients, the DFI therapy in this study primarily involved debridement of necrotic tissue, supplemented by daily dressings and intravenous (IV) antibiotics until full healing of ulcer. Intravenous antibiotics were administered in 34.6% of cases alongside topical therapy, which comprised medicated skin patches, antibiotic creams, or Farmactive hydrogel until full healing. Among patients undergoing more invasive procedures—such as ray amputation, forefoot amputation, or below-knee amputation—an alarming 12.8% report significant clinical repercussions from advanced DFI. Prior research indicates that rapid surgical debridement combined with targeted antibiotic therapy diminishes infection severity and accelerates wound healing (Pittam et al., 2022). This study advocates for comprehensive therapeutic strategies to reduce amputation rates and enhance clinical outcomes in patients with diabetic foot, particularly in cases of substantial amputations (Vuorlaakso et al., 2024). These findings emphasize the pressing necessity for rapid and comprehensive treatment strategies to effectively manage diabetic foot complications.

4.3 Microorganisms isolated from diabetic foot ulcers

Our microbiological analysis of DFI revealed a predominance of Gram-negative bacteria, with Escherichia coli being the most frequently isolated pathogen (26.5%), succeeded by Staphylococcus aureus (20.9%) and Pseudomonas aeruginosa (10.9%).

Other significant isolates were Acinetobacter spp. (8.5%) and Klebsiella pneumoniae (8.1%). In 3.8% of the samples, Staphylococcus epidermidis and Enterococcus spp. were found. In 7.6% of the samples, Methicillin resistant Staphylococcus aureus (MRSA) was found. Morganella Morganii appears less often, at a rate of 2.4%. These new results add to what has already been published about diabetic foot infections being caused by more than one type of bacteria, usually both Gram-positive and Gram-negative. A full examination demonstrated that 52.4% of the isolates in DFI were Gram-negative bacteria, such as E. coli and P. aeruginosa. (Du et al., 2022). The presence of multidrug-resistant organisms like MRSA and extended-spectrum beta-lactamase (ESBL)-producing Enterobacteriaceae makes treating DFIs more challenging. Bader's research investigating of MRSA at DFIs in China pointed out how important it is to use the right antibiotics to stop the development of resistance. (Xie et al., 2024).

4.4 Patterns of antibiotic sensitivity

Our research shows how challenging multidrug-resistant organisms are in DFI by showing how sensitive they are to antibiotics. Meropenem and Ertapenem were the most effective, with sensitivity rates of 63.03%. Amikacin was next, with a rate of 47.39%. Gentamicin (40.28%), piperacillin/tazobactam (39.81%), ciprofloxacin/ levofloxacin (38.86%), and cephalosporin's (3^{rd} generation group) (38.39%) were some of the other antibiotics that were moderately sensitive. The sensitivity rates for vancomycin, clindamycin, and tetracycline/doxycycline were 26.54%, 25.12%, and 20.85%, respectively. The lowest sensitivity rate was for amoxicillin-clavulanic acid at 3.79%.

These findings are consistent with previous research demonstrating that DFIs typically include multidrug-resistant Gram-negative bacteria. A research indicated that, although resistance to routinely used antibiotics such as amoxicillin-clavulanic acid was particularly severe, Carbapenems—including meropenem—were among the most successful therapies for Gram-negative bacteria in diabetic foot infections (Ismail et al., 2021). The Infectious Diseases Society of America (IDSA) suggests Carbapenems and fluoroquinolones as preferable therapy choices for infections caused by Enterobacteriaceae, which are frequently prevalent in diabetic foot infections,

particularly those with extended-spectrum beta-lactamase producing potential. (Tamma et al., 2022).

The limited effectiveness of several antibiotics shows the need for culture-guided therapy and the ongoing monitoring of antimicrobial resistance patterns in DFI. Enhancing therapeutic outcomes and mitigating the proliferation of resistant infections necessitate the personalization of antibiotic therapy based on susceptibility profiles.

4.5 Antibiotics prescribed for patients

In our study, Meropenem was the most often prescribed antibiotic, indicated for 28.9% of patients with DFI. This tendency aligns with its extensive efficacy against both Gram-positive and Gram-negative bacteria, including multidrug-resistant variants, hence informing the management of severe diabetic foot infections (Fish, 2006). Piperacillin/Tazobactam (15.2%) and Ciprofloxacin (14.7%) were extensively utilized, demonstrating their effectiveness against Gram-positive pathogens and some Gram-negative bacteria, respectively. Vancomycin (9.9%) and clindamycin (9.0%) were prescribed less often, perhaps reserved for cases of resistant Gram-positive infections, such as those caused by MRSA.

A reduced proportion of patients—potentially due to emerging resistance patterns in Gram-negative bacteria—utilized cephalosporin's such as Ceftaxime (7.1%), Ceftazidime (6.1%), and Ceftriaxone (5.2%). The antibiotic least suggested (3.7%), amoxicillin-clavulanic acid, exhibits inadequate efficacy against resistant microorganisms commonly associated with diabetic foot infections, which may elucidate its reduced usage (Darwis et al., 2021).

4.6 Association between ulcer grade and medical history

Our analysis reveals a statistically significant correlation between nephropathy and elevated ulcer grades, aligning with existing literature. Specifically, those with nephropathy exhibited more severe ulcers, predominantly Grade D (34.6%) and Grade E (7.7%), compared to those without nephropathy. A narrative review indicates that diabetic nephropathy is associated with an increased prevalence of severe DFU, hence corroborating this association. Research on patients with diabetes and chronic kidney

disease (CKD) has demonstrated a higher incidence of foot ulcers and worse healing outcomes. Nephropathy may exacerbate neuropathy and peripheral artery disease, hence intensifying the severity of DFU (Bonnet and Sultan, 2022).

Our analysis reveals a statistically significant association between elevated HBA1C and ulcer grades, which emphasis that the patients with poor glycemic control have had high grade ulcer with more infections, poor healing and poor compliance, with the result of more complications (Akyüz et al., 2023).

4.7 Strengths of the study

- The study encompassed 211 patients, yielding a substantial sample size for dependable statistical analysis.
- It meticulously documented demographic data, clinical attributes (ulcer location, grade, stage), microbiological profiles, antibiotic susceptibility patterns, and treatment results.
- The research utilized established grading and staging procedures for diabetic foot ulcers, enhancing comparability with previous investigations.
- The study elucidated patterns in antibiotic resistance in diabetic foot infections, offering therapeutically significant information for the selection of appropriate empirical therapy.
- The study referenced contemporary worldwide research (2021–2024), ensuring the findings correspond with current medical knowledge.

4.8 Limitations of the Study

- Data were obtained from a single hospital or location, thus restricting the applicability of the findings to other contexts or populations.
- The study was retrospective, without randomization or a control group, which complicates the establishment of causation.

- The research evaluated immediate treatment results but did not conduct long-term follow-up on patients to examine wound healing, recurrence, death, or re-hospitalization.

- The retrospective study, limited the ability to collect information like: medications used by admitted patients for diabetes before admission, and history of ulcer (recurrent ulcer, long time of this ulcer).

4.9 Conclusion

The study confirms the major burden and complexity of DFI, which generally show as gangrene accompanied by ischemia and DFUs. The microbiological profiles revealed a high prevalence of Gram-negative bacteria, notably Escherichia coli, and Pseudomonas aeruginosa, accompanied by considerable treatment resistance. Meropenem, along with other Carbapenems, was the most often prescribed and effective antibiotic. The significant relationship between nephropathy and severe ulceration underscores the necessity for targeted interventions in diabetes patients with renal complications. The results affirm the necessity for multidisciplinary, assertive management strategies that encompass early detection, prompt surgical and antimicrobial interventions, and tailored patient care plans to enhance clinical outcomes and reduce the incidence of severe complications, including amputations.

4.10 Recommendations

- It is recommended to implement routine multidisciplinary assessments for high-risk patients such as diabetic patients, especially those with nephropathy and poorly controlled patients.

- It is recommended to adopt culture-guided antibiotic therapy protocols due to the diverse microbial spectrum and significant antibiotic resistance observed, healthcare facilities should standardize the use of microbiological cultures and sensitivity testing to guide antibiotic selection.

- It is recommended to give preventive foot care education provided by physicians and pharmacists, in addition to screening programs to reduce ulcer severity and prevent progression to gangrene or amputation.

- It is recommended to include clinical pharmacists in the healthcare team of diabetic patients to improve disease control and decrease complications.

List of Abbreviations

Abbreviation	Meaning
DM	Diabetes mellitus
T2DM	Type 2 diabetes mellitus
PMOH	Palestinian ministry of health
DFI	Diabetic foot infection
RBS	Random Blood Sugar
DFU	Diabetic foot ulcer
MDROs	multidrug-resistant organisms

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Appendices

Appendix A

Data Collection Form

Section A: Demographic Information

- Patient file number: _____
- Age: _____
- Gender: _____
- Duration of Diabetes Mellitus: _____
- Comorbidities (e.g., hypertension, cardiovascular disease):
  _____

Section B: Clinical Characteristics of diabetic foot

- Ulcer grade (Wagner or IDSA classification):
  _____
- Presence of neuropathy or peripheral vascular disease: Yes No
- Duration of ulcer: _____

Section C: Laboratory Findings

- Type of bacterial isolate(s) identified:
  _____
- Antibiotic susceptibility results (using standard susceptibility testing methods):
  _____
  _____
  _____
  _____

Section D: Treatment and Outcomes

- Antibiotic treatment regimen:
  _____
- Duration of each antibiotic use:
  _____

- Other treatments and procedures: _____
- Length of hospital stay: _____
- Outcomes (e.g., wound healing, amputation).: _____

Appendix B

IRB approval

جـــامـعـة النـجـاح الـوطـنـيـة
An-Najah National University

مكتب مجلس المراجعة المؤسسية
Office of Institutional Review Board (IRB)

Dear Dr. Rowa Jamal Al –Rmahi,

We are pleased to inform you that your research proposal titled **"Bacterial profile and antibiotic susceptibility patterns in hospitalized patients with infected diabetic foot"** has been approved by the Institutional Review Board (IRB) at **An-Najah National University**.

Here are the approval details:

Submitted by:	Rowa Jamal Al –Rmahi, Aseel Khader Mohammad Hammad
Approval Date:	28th November. 2024
IRB Protocol Number:	Pharm. Nov. 2024/39

Please report any changes to the study protocol to the IRB for review. If you have any questions, contact us at **irb@najah.edu**. Thank you for your commitment to ethical research.

Best regards,

Naim Kittana, Dr.

IRB, Chairperson

IRB
Institutional Review Board

University
Nablus , Palestine - Tel : +972(9)2345113 - EX. 88- 4323 - Fax :+972(9)2345982 - E: info@najah.edu
Department
irb@najah.edu
ANajahUni
https:// www.najah.edu

Appendix C

Ministry of Health approval

State of Palestine
Ministry of Health
Education in Health and Scientific
Research Unit

دولة فلسطين
وزارة الصحة
وحدة التعليم الصحي
والبحث العلمي

Ref.: .....
Date:.....

الرقم: ع ت/ ٢٢٢٨/ ٢٠٢١
التاريخ: ٢٠٢١/٠٤/٢٦

الاخ مدير عام الادارة العامة للمستشفيات المحترم،،،
الاخت ق. أ. مدير عام الادارة العامة لتكنولوجيا المعلومات المحترم،،،
تحية واحترام،،

الموضـــوع: تسهيل مهمة بحث

يرجى تسهيل مهمة الطالبة: **أسيل خضر حماد- برنامج صيدلة سريرية- جامعة النجاح**، لعمل بحث الماجستير بعنوان:

الملف البكتيري وأنماط حساسية المضادات الحيوية لدى المرضى المقيمين في المستشفى المصابين بالتهاب القدم السكري

حيث ستقوم الباحثة بجمع معلومات عن طريق الاطلاع على ملفات المرضى دون الحصول على المعلومات التعريفية لهم، وباشراف مسؤولي الملفات، وذلك في:

- **مستشفى سلفيت**

مع العلم أن مشرفي الدراسة: د.رواء الرمحي.

على ان يتم الالتزام بالمحافظة على اخلاقيات البحث العلمي وسرية المعلومات، وعدم التعرض للمعلومات الشخصية للمشاركين.
على ان يتم تزويد الوزارة بنسخة PDF من نتائج البحث، التعهد بعدم النشر لحين الحصول على موافقة وزارة الصحة.

مع الاحترام،،

د. عبد الله القواسمي
رئيس وحدة التعليم الصحي والبحث العلمي

نسخة: نائب الرئيس للشؤون الاكاديمية المحترم / جامعة النجاح

دولة فلسطين وزارة الصحة وحدة التعليم الصحي والبحث العلمي

Telfax.:09-2333901 scientificresearch.dep@gmail.com تلفاكس: 09-2333901

Appendix D

Tables of Study

Table D1

Association between amikacin sensitivity and microorganisms

Microorganism	Antibiotic name Amikacin				X2	P-value
	No		Yes			
	N	%	N	%		
Escherichia coli	22	19.8%	34	34.0%	49.465a	<0.001*
Staphylococcus aureus	34	30.6%	10	10.0%		
Clostridium	2	1.8%	0	0.0%		
Pseudomonas aeruginosa	9	8.1%	14	14.0%		
Escherichia coli + Klebsiella pneumoniae	0	0.0%	1	1.0%		
Pseudomonas aeruginosa + MRSA	1	0.9%	2	2.0%		
Morganella Morganii	1	0.9%	4	4.0%		
Staphylococcus epidermidis	6	5.4%	2	2.0%		
Acinetobacter	2	1.8%	0	0.0%		
Enterococcus spp.	6	5.4%	2	2.0%		
Klebsiella pneumoniae	5	4.5%	12	12.0%		
Acinetobacter spp.	7	6.3%	11	11.0%		
Escherichia coli + Pseudomonas	1	0.9%	1	1.0%		
Escherichia coli + Staphylococcus aureus	0	0.0%	2	2.0%		
Methicillin-resistant Staphylococcus aureus (MRSA)	15	13.5%	1	1.0%		
Enterobacter spp	0	0.0%	3	3.0%		
Providencia Stuartii	0	0.0%	1	1.0%		

Table D2

Association between Amoxicillin/Clavulanic acid sensitivity and microorganisms

Microorganism	Antibiotic name Amoxicillin + Clavulanic acid				X2	P-value
	No		Yes			
	N	%	n	%		
Escherichia coli	54	26.6%	2	25.0%	32.269	.009*
Staphylococcus aureus	42	20.7%	2	25.0%		
Clostridium	2	1.0%	0	0.0%		
Pseudomonas aeruginosa	23	11.3%	0	0.0%		
Escherichia coli + Klebsiella pneumoniae	1	0.5%	0	0.0%		
Pseudomonas aeruginosa + MRSA	3	1.5%	0	0.0%		
Morganella Morganii	4	2.0%	1	12.5%		
Staphylococcus epidermidis	8	3.9%	0	0.0%		
Acinetobacter	2	1.0%	0	0.0%		
Enterococcus spp.	8	3.9%	0	0.0%		
Klebsiella pneumoniae	17	8.4%	0	0.0%		
Acinetobacter spp.	17	8.4%	1	12.5%		
Escherichia coli + Pseudomonas	2	1.0%	0	0.0%		
Escherichia coli + Staphylococcus aureus	2	1.0%	0	0.0%		
Methicillin-resistant Staphylococcus aureus (MRSA)	15	7.4%	1	12.5%		
Enterobacter spp	3	1.5%	0	0.0%		
Providencia Stuartii	0	0.0%	1	12.5%		

Table D3

Association between Cephalosporins sensitivity and microorganisms

Microorganism	Antibiotic name Cephalosporin's(3rd generation group)				X2	P-value
	No		Yes			
	N	%	n	%		
Escherichia coli	32	24.6%	24	29.6%	19.464	0.245
Staphylococcus aureus	25	19.2%	19	23.5%		
Clostridium	0	0.0%	2	2.5%		
Pseudomonas aeruginosa	17	13.1%	6	7.4%		
Escherichia coli + Klebsiella pneumoniae	0	0.0%	1	1.2%		
Pseudomonas aeruginosa + MRSA	2	1.5%	1	1.2%		
Morganella Morganii	1	0.8%	4	4.9%		
Staphylococcus epidermidis	4	3.1%	4	4.9%		
Acinetobacter	2	1.5%	0	0.0%		
Enterococcus spp.	6	4.6%	2	2.5%		
Klebsiella pneumoniae	12	9.2%	5	6.2%		
Acinetobacter spp.	10	7.7%	8	9.9%		
Escherichia coli + Pseudomonas	1	0.8%	1	1.2%		
Escherichia coli + Staphylococcus aureus	1	0.8%	1	1.2%		
Methicillin-resistant Staphylococcus aureus (MRSA)	14	10.8%	2	2.5%		
Enterobacter spp	2	1.5%	1	1.2%		
Providencia Stuartii	1	0.8%	0	0.0%		

Table D4

Association between Ciprofloxacin/Levofloxacin sensitivity and microorganisms

Microorganism	Antibiotic name Ciprofloxacin / Levofloxacin				X2	P-value
	No		Yes			
	N	%	n	%		
Escherichia coli	36	27.9%	20	24.4%	16.993	.386
Staphylococcus aureus	26	20.2%	18	22.0%		
Clostridium	2	1.6%	0	0.0%		
Pseudomonas aeruginosa	13	10.1%	10	12.2%		
Escherichia coli + Klebsiella pneumoniae	0	0.0%	1	1.2%		
Pseudomonas aeruginosa + MRSA	2	1.6%	1	1.2%		
Morganella Morganii	2	1.6%	3	3.7%		
Staphylococcus epidermidis	5	3.9%	3	3.7%		
Acinetobacter	2	1.6%	0	0.0%		
Enterococcus spp.	5	3.9%	3	3.7%		
Klebsiella pneumoniae	7	5.4%	10	12.2%		
Acinetobacter spp.	13	10.1%	5	6.1%		
Escherichia coli + Pseudomonas	0	0.0%	2	2.4%		
Escherichia coli + Staphylococcus aureus	1	0.8%	1	1.2%		
Methicillin-resistant Staphylococcus aureus (MRSA)	13	10.1%	3	3.7%		
Enterobacter spp	2	1.6%	1	1.2%		
Providencia Stuartii	0	0.0%	1	1.2%		

Table D5

Association between Tetracycline/Doxycycline sensitivity and microorganisms

Microorganism	Antibiotic name Tetracycline / Doxycycline				X2	P-value
	No		Yes			
	N	%	n	%		
Escherichia coli	54	32.3%	2	4.5%	72.334	<0.001*
Staphylococcus aureus	20	12.0%	24	54.5%		
Clostridium	2	1.2%	0	0.0%		
Pseudomonas aeruginosa	23	13.8%	0	0.0%		
Escherichia coli + Klebsiella pneumoniae	1	0.6%	0	0.0%		
Pseudomonas aeruginosa + MRSA	1	0.6%	2	4.5%		
Morganella Morganii	5	3.0%	0	0.0%		
Staphylococcus epidermidis	4	2.4%	4	9.1%		
Acinetobacter	1	0.6%	1	2.3%		
Enterococcus spp.	6	3.6%	2	4.5%		
Klebsiella pneumoniae	17	10.2%	0	0.0%		
Acinetobacter spp.	17	10.2%	1	2.3%		
Escherichia coli + Pseudomonas	2	1.2%	0	0.0%		
Escherichia coli + Staphylococcus aureus	1	0.6%	1	2.3%		
Methicillin-resistant Staphylococcus aureus (MRSA)	9	5.4%	7	15.9%		
Enterobacter spp	3	1.8%	0	0.0%		
Providencia Stuartii	1	0.6%	0	0.0%		

Table D6

Association between Gentamycin sensitivity and microorganisms

Microorganism	Antibiotic name Gentamycin				X2	P-value
	No		Yes			
	N	%	n	%		
Escherichia coli	34	27.0%	22	25.9%	24.434	.080
Staphylococcus aureus	20	15.9%	24	28.2%		
Clostridium	2	1.6%	0	0.0%		
Pseudomonas aeruginosa	15	11.9%	8	9.4%		
Escherichia coli + Klebsiella pneumoniae	0	0.0%	1	1.2%		
Pseudomonas aeruginosa + MRSA	3	2.4%	0	0.0%		
Morganella Morganii	1	0.8%	4	4.7%		
Staphylococcus epidermidis	7	5.6%	1	1.2%		
Acinetobacter	2	1.6%	0	0.0%		
Enterococcus spp.	4	3.2%	4	4.7%		
Klebsiella pneumoniae	10	7.9%	7	8.2%		
Acinetobacter spp.	15	11.9%	3	3.5%		
Escherichia coli + Pseudomonas	2	1.6%	0	0.0%		
Escherichia coli + Staphylococcus aureus	1	0.8%	1	1.2%		
Methicillin-resistant Staphylococcus aureus (MRSA)	9	7.1%	7	8.2%		
Enterobacter spp	1	0.8%	2	2.4%		
Providencia Stuartii	0	0.0%	1	1.2%		

Table D7

Association between Clindamycin sensitivity and microorganisms

Microorganism	Antibiotic name Clindamycin				X2	P-value
	No		Yes			
	N	%	n	%		
Escherichia coli	54	34.2%	2	3.8%	121.924	<0.001*
Staphylococcus aureus	9	5.7%	35	66.0%		
Clostridium	0	0.0%	2	3.8%		
Pseudomonas aeruginosa	23	14.6%	0	0.0%		
Escherichia coli + Klebsiella pneumoniae	1	0.6%	0	0.0%		
Pseudomonas aeruginosa + MRSA	1	0.6%	2	3.8%		
Morganella Morganii	5	3.2%	0	0.0%		
Staphylococcus epidermidis	5	3.2%	3	5.7%		
Acinetobacter	2	1.3%	0	0.0%		
Enterococcus spp.	7	4.4%	1	1.9%		
Klebsiella pneumoniae	17	10.8%	0	0.0%		
Acinetobacter spp.	18	11.4%	0	0.0%		
Escherichia coli + Pseudomonas	2	1.3%	0	0.0%		
Escherichia coli + Staphylococcus aureus	1	0.6%	1	1.9%		
Methicillin-resistant Staphylococcus aureus (MRSA)	10	6.3%	6	11.3%		
Enterobacter spp	3	1.9%	0	0.0%		
Providencia Stuartii	0	0.0%	1	1.9%		

Table D8

Association between Vancomycin sensitivity and microorganisms

Microorganism	Antibiotic name Vancomycin				X2	P-value
	No		Yes			
	N	%	n	%		
Escherichia coli	55	35.5%	1	1.8%	113.045	<0.001*
Staphylococcus aureus	18	11.6%	26	46.4%		
Clostridium	2	1.3%	0	0.0%		
Pseudomonas aeruginosa	23	14.8%	0	0.0%		
Escherichia coli + Klebsiella pneumonia	1	0.6%	0	0.0%		
Pseudomonas aeruginosa + MRSA	1	0.6%	2	3.6%		
Morganella Morganii	5	3.2%	0	0.0%		
Staphylococcus epidermidis	1	0.6%	7	12.5%		
Acinetobacter	1	0.6%	1	1.8%		
Enterococcus spp.	2	1.3%	6	10.7%		
Klebsiella pneumonia	17	11.0%	0	0.0%		
Acinetobacter spp.	18	11.6%	0	0.0%		
Escherichia coli + Pseudomonas	2	1.3%	0	0.0%		
Escherichia coli + Staphylococcus aureus	1	0.6%	1	1.8%		
Methicillin-resistant Staphylococcus aureus (MRSA)	5	3.2%	11	19.6%		
Enterobacter spp	3	1.9%	0	0.0%		
Providencia Stuartii	0	0.0%	1	1.8%		

جـامعـــة النجاح الوطنية

كليـــة الدراســـات العليـــا

الملف البكتيري وأنماط حساسية المضادات الحيوية لدى المرضى المقيمين في المستشفى المصابين بالتهاب القدم السكري

إعداد

أسيل خضر حماد

إشراف

أ. د. رواء الرمحي

قدمت هذه الرسالة استكمالا لمتطلبات الحصول على درجة الماجستير في الصيدلة السريرية، من كلية الدراسات العليا، في جامعة النجاح الوطنية، نابلس– فلسطين.

2025

الملف البكتيري وأنماط حساسية المضادات الحيوية لدى المرضى المقيمين في المستشفى المصابين بالتهاب القدم السكري

إعداد

أسيل خضر حماد

إشراف

أ. د. رواء الرمحي

الملخص

مقدمة: يعتبر مرض السكري من المشكلات الصحية العامة والأكثر شيوعاً، وقد ارتبط بشكل متزايد في السنوات الأخيرة بحدوث مضاعفات خطيرة. أحد هذه المضاعفات المعقدة والمكلفة وهو التهاب القدم السكري. إن التشخيص المبكر لتقرحات القدم السكري اضافة الى البدء بالعلاج المناسب والوقت المناسب بناء على معرفة مسبب المرض واختبار حساسية المضاد الحيوي يؤدي الى تحقيق نتائج سريرية إيجابية.

أن الهدف من هذه الدراسة هو تقييم الأنماط البكتيرية ومدى استجابتها للمضادات الحيوية لدى المرضى المصابين بالتهاب القدم السكري.

المنهجية: تم استخدام تصميم دراسة استعادية لتحليل الأنماط البكتيرية وأنماط الحساسية للمضادات الحيوية لدى المرضى المصابين بتقرحات القدم السكري في مستشفى سلفيت الحكومي. شملت الدراسة ملفات جميع المرضى الذين حققوا معايير الاشتمال خلال السنوات الثالثة الماضية (من سنه 2021 حتى سنة 2024). تم استخدام برنامج التحليل الاحصائي SPSS لتحليل البيانات.

النتائج: شملت الدراسة: 211 مريض. وكانت الفئة العمرية من عمر 50–59 عام، تشكل 45% ونسبة الذكور 66.8%. بالنسبة لمدة الإصابة بمرض السكري فقد كان 87.2% مصابين بمرض السكري أكثر من عشر سنوات. ووجد ان 34.6% من المرضى يعانون من الاعتلال العصبي، 24.6% يعانون من

اعتلال كلوي، 8.5% يعانون من اعتلال بالأوعية الدموية. بالنسبة لمكان القرحة الناتجة عن التهاب القدم السكري: كانت النسب كالاتي: 33.1% في منتصف القدم، 28% في قاعدة إصبع الابهام من القدم، 19.7% قاعدة الاصبع الصغير من القدم. وكانت أكثر أنواع البكتيريا شيوعا: E. coli بنسبة 26%، S. Aureus بنسبة 20.9%، Pseudomonas بنسبة 10.9%. من حيث الاستجابة للمضادات الحيوية: كان ال meropenem بنسبة استجابة 63%، يليه ال amikacin بنسبة 47.39%، الgentamycin بنسبة 40.28%tazobactam + piperacillin بنسبة 39.8%، fluoroquinolones بنسبة 38.86%،cephalosporin بنسبة 38.39%، vancomycin بنسبة 26.54%، clindamycin بنسبة 25.12%، doxycycline بنسبة 20.85%، amoxicillin +clavulanic acid بنسبة 3.79%.

الخلاصة: أظهرت النتائج ان البكتيريا gram negative هي الأكثر شيوعا، مع وجود مقاومة ملحوظه للعلاج. وكان المضاد الحيوي ال meropenem الأكثر فعالية واستخداما._تؤكد هذه النتائج على ضرورة وجود استراتيجيات علاجيه متعددة التخصصات، تشمل الكشف المبكر، والتدخل الجراحي المناسب، والمضاد الحيوي الفعال، ووضع خطة علاجيه فرديه لكل مريض حسب وضعه الصحي ودرجة الالتهاب والعوامل المصاحبة للقدم السكري._وذلك بهدف تحسين النتائج السريرية وتقليل المضاعفات الخطيرة المتمثلة ببتر الطرف المصاب.

الكلمات المفتاحية: تقرح القدم السكري، الاستجابة للمضادات الحيوية، انواع البكتيريا، فلسطين.